Water Standards and Studies Report No. 88-3

Nutrient Enrichment Study of Shoal Lake (Western Manitoba)

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Manitoba
Environment and
Workplace Safety
and Health

NUTRIENT ENRICHMENT STUDY
OF
SHOAL LAKE (WESTERN MANITOBA)

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Department of Environment and Workplace Safety and Health
Water Standards and Studies Report #88-3

SUMMARY

The Council of the R.M. of Shoal Lake requested the Manitoba Department of Environment and Workplace Safety and Health to conduct a water quality study on Shoal Lake. The ultimate intent of the project was to develop a realistic and effective strategy for rehabilitation of lake water quality such that the aesthetic and recreational appeal of the lake would be restored. The goal of the present study was to provide a baseline for such a strategy by defining the severity of the problem and by identifying and quantifying the causes of the problem.

The study commenced in March, 1987 as a joint effort between the Councils of the R.M. and of the Village of Shoal Lake and Water Standards and Studies Section of the Manitoba Department of Environment and Workplace Safety and Health. The Councils' responsibilities included sample collection and provision of necessary background information. The responsibilities of Water Standards and Studies Section included sample analyses, data interpretation and report preparation. Interpretive aids and applied procedures included assessment of trophic status, identification of the problem nutrient and development and validation of a phosphorus budget.

As suggested by the occurrence of extensive blue-green algae blooms, Shoal Lake was found to be a hyper-eutrophic waterbody. This means that the water is very rich in nutrients, that biological productivity is very high and that the water quality generally was not suitable for body contact recreational purposes. Phosphorus was confirmed as the problem nutrient which controlled algae and macrophyte production in Shoal Lake. Internal recycling from lake sediments accounted for approximately 51.9% of the total phosphorus loading to the water column of Shoal Lake. Phosphorus release from sediments during anoxia was estimated at 1402 Kg per year and effective phosphorus realse from sediments due to wind induced turbulence was estimated at 626.9 Kg per year. Runoff from the drainage basin accounted for approximatey 77.5% of gross external loading. Excessive phosphorus loadings within the drainage basin were attributed primarily to concentrated livestock holdings located along the Oak River within approximately 1.5 km upstream of Shoal Lake and secondarily to pastures which straddled the Oak River at sites several kilometres further upstream. Approximately 10.7% of the gross external phosphorus loading to Shoal Lake was attributable to the Village of Shoal Lake sewage lagoon discharges and approximately 10.4% was attributable to precipitation, dust and other materials aerially deposited. Phosphorus loadings attributable to rural residences, cottages and campground were estimated at approximately 1.5% of the gross external load.

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1.0 INTRODUCTION

Shoal Lake (50°24',100°36') is located approximately 250 kilometres west-north-west of Winnipeg and approximately 40 kilometres south of Riding Mountain National Park (Figure 1). The lake has a surface area of approximately 476 hectares, a maximum length of approximately 7.0 kilometres and a maximum depth of 4.8 metres. It is located within the R.M. of Shoal Lake. The Village of Shoal Lake is situated at the northern end of the lake.

Shoal Lake has a history of water quality problems and of activist groups attempting to address the issue. Virtually all of the water quality concerns dealt with excessive growths of blue-green algae (Cyanophyte blooms). Remedial actions undertaken typically focussed upon treatment of the symptom (Cyanophyte blooms) rather than upon the cause (excessive nutrient loadings). Examples include the 1959-60 construction of an improved swimming area by the Shoal Lake Improvement Committee and the copper sulfate-hydrated lime treatments by the Shoal Lake Lions Club commencing in 1973 (Adams, 1973).

More recently, Mr. Dick Edmundson (Reeve, R.M. of Shoal Lake) requested that Water Standards and Studies Section staff meet with Council of the R.M. of Shoal Lake to discuss the possibility of corrective action. An exploratory meeting to this end was held on November 5, 1986 and firm commitments were made at a subsequent meeting held on March 17, 1987. Councillors from both the R.M. of Shoal Lake and the Village of Shoal Lake participated in the latter meeting, thereby signifying a joint desire to resolve the problem and

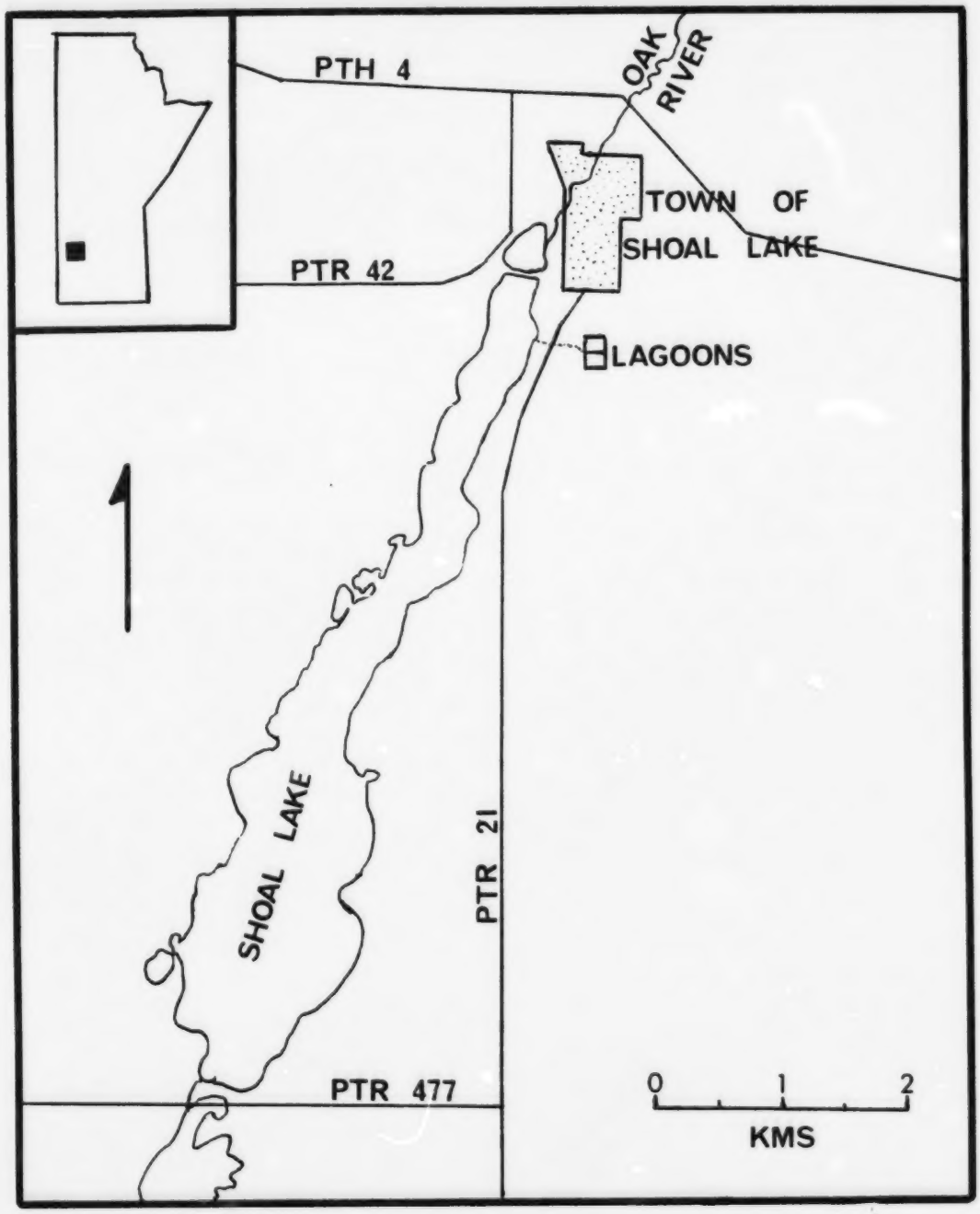

Figure 1: The Shoal Lake study area.

a joint commitment for action. The basic understanding achieved at the latter meeting was that the R.M. and the Village were to provide essential information and to collect and submit the necessary samples. Water Standards and Studies was to provide essential equipment, sample analyses, data interpretation and report preparation.

The goal of the R.M. and Village Councils was to develop a lake restoration strategy which, when implemented, would improve the water quality of Shoal Lake as well as enhance fish habitat and the lake's recreational value. The intent of the present study was to facilitate achievement of the Council's goal by defining the extent of the problem as well as identifying and quantifying the sources of nutrient loading. The specific objectives of the present report are:

1. to define the trophic status of Shoal Lake;
2. to identify the problem nutrient(s);
3. to develop a valid budget for the problem nutrient(s);
4. to identify the sources of the problem nutrient inputs;
5. to quantify the problem nutrient inputs.

The present report was not intended to provide an itemized restoration strategy. Rather, the present report was to serve as a baseline reference so that an effective strategy could be developed in close concert with the Councils.

2.0 DESCRIPTION OF SHOAL LAKE AND AREA

Shoal Lake (50°24',100°36') is located in a gently undulating region of western Manitoba. Gleysolic-chernozemic soils have developed on highly calcareous till (Weir, 1983). Natural vegetation is predominantly grassland with scattered groves of willow and aspen (Ibid). Immediate areas surrounding the lake are devoted nearly exclusively to agriculture, with pastoral endeavours dominating production of cereal grains. Other land uses include residential areas such as the Village of Shoal Lake (50°26',100°35') and recreational areas such as cottage developments, two campgrounds and a golf course. The Village of Shoal Lake, 1986 population of 832 (Statistics Canada, pers. comm.), acts as a service centre to the local agricultural community. The 1986 population of the R.M. of Shoal Lake was 795 (Ibid).

Shoal Lake receives drainage from a watershed of approximately 398 square kilometres. The Oak River provides the principle inflow with lesser volumes contributed by local surficial runoff and Village lagoon discharges. The mean total discharge to Shoal Lake from Oak River approximates $3.92 \times 10^6 m^3$ per annum (Inland Waters Directorate, 1987). The total discharge for 1987, the year under study, was $5.41 \times 10^6 m^3$ (D. Walker, pers. comm.).*

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* D. Walker, Hydrometeorological Technologist, Water Resources, Manitoba Department of Natural Resources.

The bulk of discharge (87% during 1987) normally occurs during the month of April. Typically, little or no flow occurs during the period September to February inclusive (op. cit.).

Shoal Lake (Figure 2) is oriented on a north-south axis with the Oak River entering and exiting at the northern and southern extremes, respectively. The surface area of the lake is approximately 476 hectares. Maximum and mean depths determined during the present study were 4.8 and 2.84 metres, respectively. The lake volume was estimated at $1.35 \times 10^7 m^3$ (June 9, 1987).

The northern tip of Shoal Lake was isolated by dykes and dredged in 1959-60 so as to replace a marsh at the edge of the Village with an enhanced swimming area (Adams, 1973). This pond measures approximately 8.6 hectares in area and has a maximum depth of 2.7 m. The pond volume was estimated at $1.1 \times 10^5 m^3$ (June 9, 1987).

Extensive Cyanophyte blooms occur virtually throughout the entire open water season. Dominant genera include Anabaena and Lyngbya. Blooms occur either as free floating colonies or as dense mats along the bottom. It is the mats which periodically lift from the bottom, drift ashore and arouse concern due to foul odors and impairment of visual aesthetics.

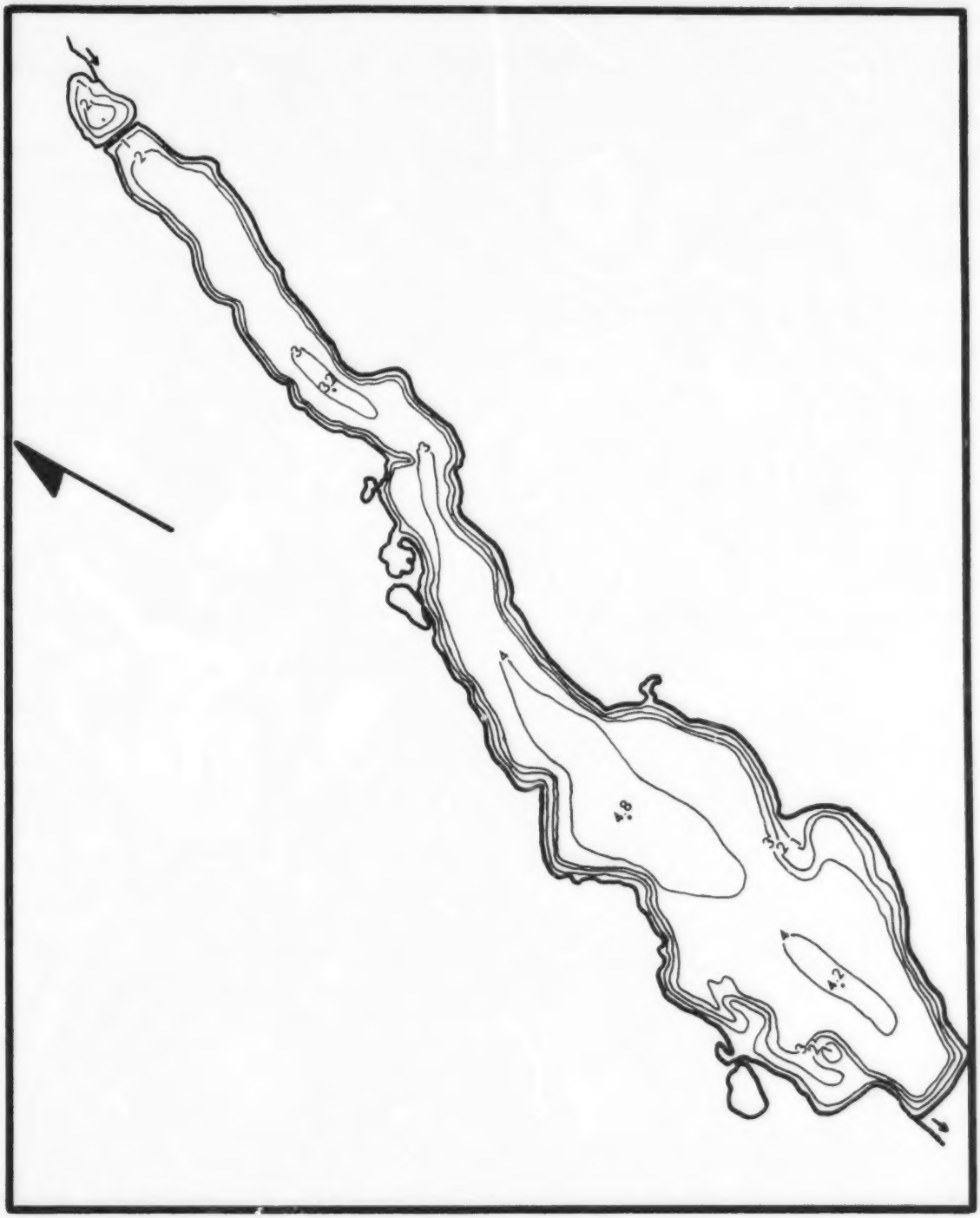

Figure 2. Contour map of Shoal Lake.

3.0 METHODS

3.1 Rationale

The ultimate intent of the Shoal Lake study was to develop a scientific background upon which a strategy for rehabilitation of lake water quality could be developed. The focus of the present study therefore, was to determine the cause(s) of the algae proliferation. Achievement of this goal required that a specific series of procedures was followed.

The classic literature (Vollenweider, 1968; Vallentyne, 1974) leaves little doubt that imprudent development along aquatic systems results in an accelerated rate of eutrophication. Accelerated eutrophication, or rapid aging of a lake, is caused by increased nutrient loading and is manifested by such symptoms as numerous algae blooms, excessive macrophyte growth and frequent fish die-offs. Classic whole lake experiments have implicated phosphorus overabundance as the trigger for accelerated eutrophication (Schindler et al, 1971; Schindler, 1977). Applying these principles to the focus of our study required that the trophic status (relative "age" or productivity) be defined, that the problem nutrient(s) be identified and that a valid budget(s) for the problem nutrient(s) be developed. Development of a valid budget(s) was critical for identification and quantitation of problem nutrient(s) sources.

3.2 Field Procedures

A rigorous water sampling regime was implemented in order to acquire a detailed and accurate data base. The primary intent of the

field sampling program was to provide an estimation of the mean total phosphorus concentration [P] at an accuracy level indicated by a mean standard error of less than 10% of the mean. Hence, the water sampling regime was based on a strategy of stratified random sampling (Cassie, 1971). Based upon previous investigations in the area (Beck, 1987), the number of lake sampling stations was set at five, summer sampling frequency was set at once weekly and fall and winter sampling frequency was set at one per term. Sampling stations (Figure 3) were located at the inlet, middle of the inlet pond, outlet and at five equidistant points along the central axis of the lake. Sampling depths were determined by considering random numbers a percentage of total depth at each station.

Samples at depth were collected using a 2.2 L pesticide grade acrylic Kemmerer sampler. Depth integrated chlorophyll "a" samples were collected at a maximum of twice the Secchi depth by using a Water Standards and Studies sampler. Instruction in proper sampling technique was provided to Mr. Dick Edmundson (Reeve, R.M. of Shoal Lake) who, with the assistance of Mr. Roy Garlick (Councillor, Village of Shoal Lake), collected the summer samples (160 samples). Fall and winter sampling (24 samples) was conducted by Water Standards and Studies Section staff.

All samples were shipped by scheduled bus service to the W.M. Ward Technical Services Laboratory so as to arrive within twenty-four hours of collection. Analyses were performed at the Laboratory according to procedures described by Sorba et al (1980).

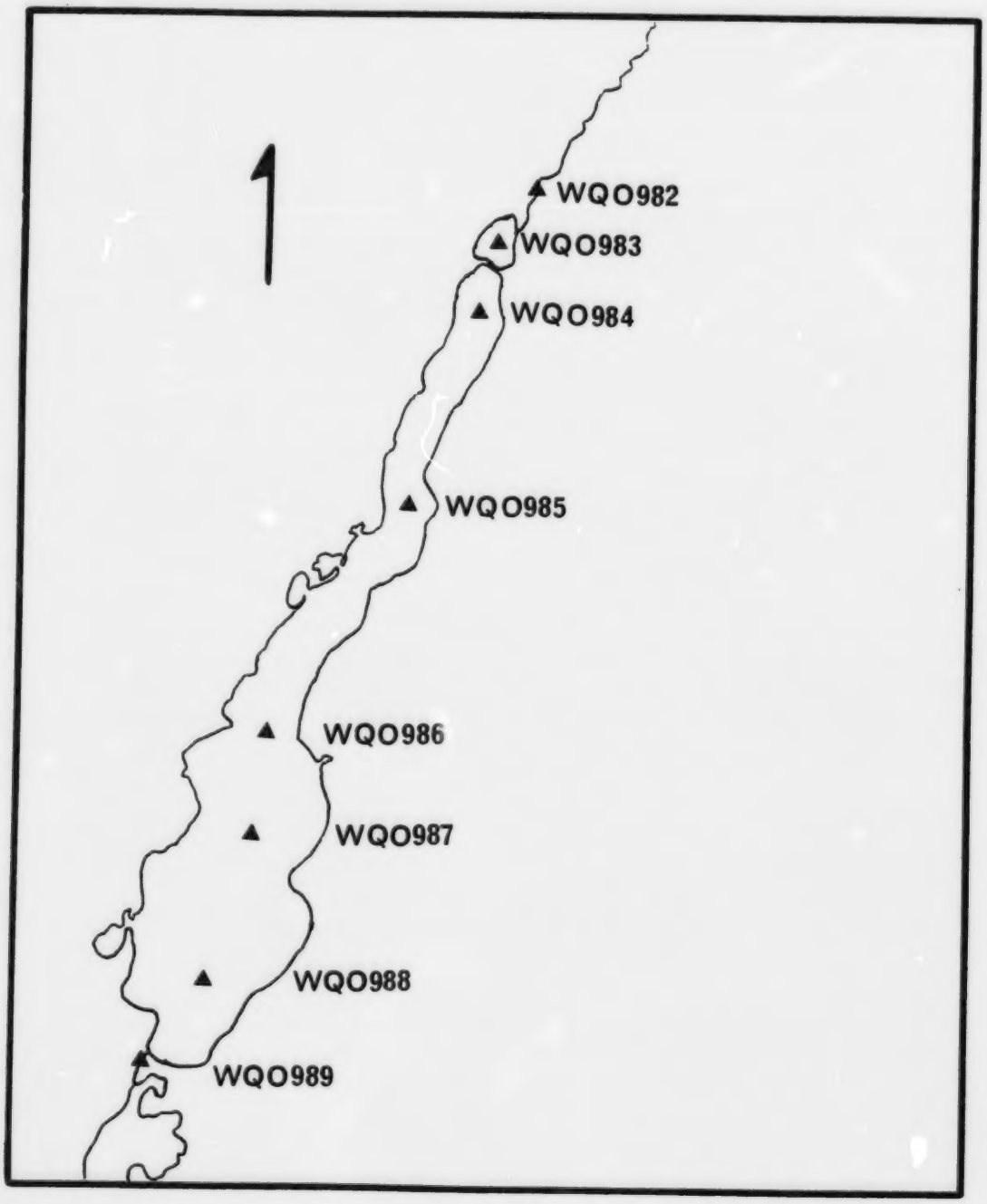

Figure 3: Sample collection sites on Shoal Lake.

3.3 Trophic Status

An understanding of aquatic systems can often be enhanced by application of broadly descriptive terms. One of the more scientifically useful terms pertains to the trophic status, or the degree of enrichment and productivity* of a particular waterbody. Four terms are generally used. Oligotrophic refers to unenriched waters of low productivity, mesotrophic refers to moderately enriched waters with moderate productivity, eutrophic refers to very enriched waters which are very productive and hypertrophic refers to extremely productive eutrophic waters. Fish kills and excessive aquatic vegetation and algae problems are experienced occasionally in mesotrophic waters. Fish kills become more common and problem growths of vegetation and algae become ever more extensive as waters become more eutrophic. Clearly defined limits of demarcation between the trophic levels generally are not encountered. Rather, the characteristics of each gradually meld with that of the next level (Vollenweider, 1968).

A variety of definitive indices or classification schemes have been proposed; four of which have gained general acceptance in North America (Rast and Lee, 1978). Two of the indices, (US EPA, 1974; Piwoni and Lee, 1975), are relatively intensive and involve a number of parameters not measured during the present study. Hence, they were not applicable to the present study. The indices of Vollenweider (1975) and Carlson (1977) were more readily applicable to the present study.

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* Within the present report, enrichment refers to nutrient availability and productivity refers to biological mass produced.

Carlson (1977) developed a numerical trophic state index graduated on a scale of 0 to 100. The index number may be calculated from secchi disk transparency, chlorophyll a or total phosphorus (Ibid). The approximate limit of demarcation between eutrophic and mesotrophic states occurs at 50 units and between mesotrophic and oligotrophic states occurs at approximately 30 units (Ibid). The computational forms of the equation (Ibid) are:

$$\text{Eq. 1.} \quad TSI(SD) = 10\left[6 - \frac{\ln SD}{\ln 2}\right];$$

$$\text{Eq. 2.} \quad TSI(Chl)^{*} = 10\left[6 - \frac{2.04 - 0.68\,(\ln Chl)}{\ln 2}\right]$$

$$\text{Eq. 3.} \quad TSI(TP)^{*} = 10\left[6 - \frac{\ln \frac{(48)}{(TP)}}{\ln 2}\right]$$

Vollenweider's (1975) scale considered a logarithmic relationship between phosphorus loading and mean depth/hydraulic residence time. The process involves plotting phosphorus loading ($g/m^2/yr$) versus mean depth/hydraulic residence time. Phosphorus loadings are estimated by the phosphorus budget calculation process.

3.4 Confirmation of Phosphorus as the Problem Nutrient

A nutrient will be consumed by aquatic vegetation at a rate proportional to the need for that nutrient (Rast and Lee, 1978). Hence, the growth of aquatic vegetation is limited by the nutrient which is available to it in the minimal quantity relative to its needs for growth or reproduction (Ibid). The nutrient most likely to limit productivity can be determined by a "demand:supply" ratio (Vallentyne, 1974). Alternately, the nutrient which is present in

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* (Chl) and (TP) are expressed as mg/m^3.

large quantities during periods of excessive aquatic vegetation growth is not limiting the growth of the macrophyte (Rast and Lee, 1978).

The demand:supply ratio may be quantified on the basis of actual vegetational requirements. The atomic ratio of nitrogen:phosphorus (i.e N:P) present in mixed phytoplankton averaged 16:1 (Redfield at al, 1963; in Rast and Lee, 1978). The atomic ratio for algae common to ponds and lakes in the south-eastern United States averaged 24:1 (Rast and Lee, 1978). Converting the atomic ratios to mass or weight (atomic weight of nitrogen = 14.01; atomic weight of phosphorus = 30.97), yields a mass N:P ratio of 7.24 mg N:1 mg P for mixed phytoplankton and 10.86 mg N:1 mg P for algae, respectively. This meant that N:P mass ratios less than the 7.24 to 10.86 range indicated that nitrogen was the limiting nutrient. Alternately, N:P mass ratios greater than the 7.24 to 10.86 range indicated that phosphorus was the limiting nutrient.

All of the nitrogen and phosphorus present is not necessarily available for immediate use by aquatic vegetation. Cowen and Lee (1976) for example, demonstrated that about 20 days were required to convert 30% of the total phosphorus to usable phosphorus (i.e. soluble orthophosphate)* and Cowen et al (1976) showed that 35 to 50 days were required to convert 70% of organic nitrogen (i.e. total Kjeldhal nitrogen) to usable ammonia, nitrate and nitrite. Our estimation

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* The soluble orthophosphate fraction was not determined in the present study because field preservation techniques are cumbersome and even relatively short terms of storage of preserved samples (i.e. <8 days) yield wide fluctuations in analytical results (El-Shaarawi and Neilson, 1984).

of the available phosphorus was derived from Hutchinson's (1957) estimate that approximately 10% of the total phosphorus present in natural water is comprised of soluble orthophosphate (i.e. readily available to aquatic vegetation). A calculated mass N:P ratio was then derived by utilizing the sum of ammonia, nitrate and nitrite forms of nitrogen and the qualified phosphorus (i.e. TP x 0.10).

3.5 Development of a Phosphorus Budget

The phosphorus budget for Shoal Lake was developed with the aid of a variety of models and data sources. The calculation process was itemized (Table 1) and discussed in a step by step fashion modified from Hough, Stansbury and Michalski Limited (1980).

Step 1:

The size of the watershed up to the point of discharge to Shoal Lake (372 Km^2) was extracted from Inland Water Directorate (1987). Estimation of the size of the remainder of the watershed was by standard hydrological procedure (Gray, 1970) wherein the high points of land surrounding the lake were outlined on a 1:50,000 NTS map. It was assumed that both surface water and groundwater flow downhill as indicated by topographic contour lines. The gross drainage area for the lake was measured with an Alpha p-27 polar planimeter.

Step 2:

Estimation of lake surface area is a standard limnological procedure (Welch, 1948). Surface areas were measured by planimetry on 1:50,000 NTS maps.

TABLE 1: CALCULATION PROCESS FOR THE SHOAL LAKE PHOSPHORUS BUDGET.

STEP	PARAMETER	QUANTITATION
1.	Gross Drainage Basin (A)	$4.03 \times 10^8 m^2$
2.	Lake Surface Area (Ao)	$4.76 \times 10^6 m^2$
3.	Drainage Basin (Ad = A-Ao)	$3.98 \times 10^8 m^2$
4.	Lake Volume (V)	$1.35 \times 10^7 m^3$
5.	Lake Mean Depth (Z = V/Ao)	2.8 m
6.	Net 1987 Runoff (r)	0.015 m/yr
7.	Net Annual Evaporation (E_V)	-0.130 m/yr
8.	Outflow $Q = [Ad \cdot r] + [E_V \cdot Ao]$	$5.35 \times 10^6 m^3/yr$
9.	Flushing Rate ($p = Q/V$)	0.40 times/yr
10.	Areal Water Load ($qs = Q/Ao$)	1.12 m/yr
11.	Retention Coefficient ($R = 13.2/13.2 + qs$)	0.92
12.	P Loading Rate for Precipitation (L_{Pr})	$41 mg/m^2/yr$
13.	P Contribution from Precipitation ($J_{Pr} = L_{Pr} \cdot Ao$)	$1.95 \times 10^8 mg/yr$
14.	P Contribution from Drainage Basin (J_D)	$1.457 \times 10^9 mg/yr$
15.	P Contribution from Sediments During Anoxia ($J_S = L_S \cdot Ao \cdot days$)	$1.402 \times 10^9 mg/yr$
16.	Total P from Sewage Lagoon (J_L)	$2.003 \times 10^8 mg/yr$
17.	P Contribution per Capita Year (S)	$8.0 \times 10^5 mg/yr.$
18.	Sewage Treatment Retention Coefficient (R_S)	0.63
19.	Total Campground Site Units (U)	38 units
20.	Mean Persons per Unit (P)	1.51 persons/unit
21.	Mean Season Length (SL)	83 days
22.	Campground Capita Years ($N_{CY}' = [U \cdot P \cdot SL]/365$)	13.05 capita years
23.	P Contribution from Campground ($J_A' = S \cdot N_{CY}' [1-R_S]$)	$3.86 \times 10^6 mg/yr$
24.	Number of Cottages (N_C)	63 units
25.	Capita Years per Cottage (P_C)	0.63 capita years
26.	Number of Residences (N_D)	10 units
27.	Capita Years per Residence (P_D)	4.3 capita years
28.	Total Occupant Capita Years ($N_{CY}'' = P_C \cdot N_C + P_D \cdot N_D$)	82.69 capita years
29.	P Contribution from Occupants ($J_A'' = S \cdot N_{CY}'' [1-R_S]$)	$2.448 \times 10^7 mg/yr$
30.	Total P from Artificial Sources ($J_A = J_A' + J_A'' + J_L$)	$2.286 \times 10^8 mg/yr$
31.	P Contribution from Wind induced turbulence ($J_w = 0.33[J_A + J_D + J_{Pr}]$)	$6.269 \times 10^8 mg/yr$
32.	Total P from Natural Sources ($J_N = J_{Pr} + J_D + J_S + J_w$)	$3.681 \times 10^9 mg/yr$
33.	Total P Supply ($J_T = J_N + J_A$)	$3.910 \times 10^9 mg/yr$
34.	Predicted Spring Total P Concentration ($P = [J_T(1-R)]/Q$)	$55.04 mg/m^3$

Step 3:

The surface area of the lake is excluded from estimations of drainage basin area due to the dynamics of evaporation (Hough, Stansbury and Michalski Limited, 1980).

Step 4:

Estimation of lake volume is a standard limnological calculation based upon lake contour maps and planimetry (Welch, 1948). The contour map of Shoal Lake was developed by Water Standards and Studies Section from soundings conducted June 9, 1987. A Furuno Mark IV unit was used for these echo soundings.

Step 5:

Estimation of mean depth is a standard limnological calculation (Welch, 1948).

Step 6:

Net 1987 runoff for the area has been estimated by the expression $r=Q_{1987}/Ad$, where $Q_{1987}=5.407 \times 10^6 m^3$ (D. Walker*, pers. comm.) and $Ad=3.72 \times 10^8 m^2$ (Inland Waters Directorate, 1987).

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* D. Walker, Hydrometeorological Technologist, Water Resources Branch; Manitoba Department of Natural Resources.

Step 7:

Because estimates of 1987 evaporation rates for the area were not available, the net annual rate provided by Mudry* (pers. comm.) has been adopted.

Steps 8, 9 and 10:

These calculations are standard load estimation procedures (Hough, Stansbury and Michalski Limited, 1980).

Step 11:

The empirical formula for estimating the relative amount of phosphorus unavailable for dispersion through the water column was provided by Dillon (no date) in Hough, Stansbury and Michalski Limited (1980). The equation replaces that proposed by Dillon and Kirchner (1975).

Step 12 and 13:

Atmospheric contribution of phosphorus can be very significant in lakes with small drainage basins (Schindler et al, 1976). Values reported by Schindler et al (1978) ranged from 24 to 53 mg/m^2/year for the Experimental Lakes Area near Kenora, Ontario. Experimental measurements of aeolian phosphorus contributions conducted near Brandon, Manitoba indicated loading rates up to

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* N. Mudry, P. Eng. Director of Planning, Water Resources Branch; Manitoba Department of Natural Resources.

82/mg/m^2/year (M. Bennett, pers. comm.*). Considering the values reported from the Experimental Lakes Area, it was deemed not unreasonable to adopt the arithmetic mean of the Brandon value (i.e. 41 mg/m^2/year) for the present study. Estimation of the total atmospheric contribution to Shoal Lake was calculated as the rate per square metre multiplied by total surface area of the lake.

Step 14:

The 1987 phosphorus contribution from the Oak River was estimated by the expression $J_{Do} = \sum P_i \cdot Q_i$;

where J_{Do} = Oak River phosphorus contribution (mg) in 1987;

P_i = phosphorus concentration (mg/L) at station WQ982 at the i_{th} sampling interval (Appendix I)

Q_i = volume of discharge (L) during the i_{th} sampling interval (D. Walker, pers. com.).

Accordingly, J_{Do} was estimated at 1.362×10^9 mg. The phosphorus contribution from the remainder of the Shoal Lake watershed (i.e. that portion immediately surrounding the lake) was estimated by the expression $J_{Ds} = [As/Ao] \cdot J_{Do}$;

where J_{Ds} = immediate Shoal Lake watershed phosphorus contribution (mg) in 1987;

A_s = area of the immediate Shoal Lake watershed (m);

A_o = area of the Oak River watershed up to Station WQ982 (m);

J_{Do} = Oak River phosphorus contribution (mg) in 1987.

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* M. Bennett, Special Projects Coordinator, Air Standards and Studies, Manitoba Department of Environment and Workplace Safety and Health.

Accordingly, J_{Ds} was estimated at 9.519×10^7 mg. The total phosphorus contribution from the entire Shoal Lake watershed was then estimated by the summation of J_{Do} and J_{Ds}.

Step 15:

Vollenweider (1975), Dillon (1975), and Nurnberg (1984) report that a net release of phosphorus occurs from lake sediments during anoxia. A mean of Vollenweider's (1975) estimates of daily phosphorus releases from sediments (L_s = 9.5 mg/m^2/day) has been adopted for the present study. Because of the variability in the date of onset of anoxia, the average duration of anoxic conditions could only be estimated in a crude fashion. It was assumed that anoxia would occur midway between the last recorded oxygen presence (February 24, 1988) and the earliest observed instance of complete anoxia (March 17, 1987). The years were disregarded in an effort to provide a value (March 5) more indicative of a true mean rather than an actual date for any specific year. Cessation of anoxia was assumed to coincide with initial infiltrations of spring meltwater. Initial infiltrations were observed on April 4, 1987 (D. Edmundson, pers. com.m).

Step 16:

The total phosphorus contributed during the 1987 drawdown of the Town sewage lagoon was estimated by the expression $J_L = V_L \cdot [P_L]$;

where J_L = total phosphorus (mg) from the 1987 lagoon drawdown;

V_L = volume (L) discharged during the 1987 drawdown;

$[P_L]$ = mean phosphorus concentration (mg/L) of the 1987 lagoon effluent.

The estimate of V_L was derived by assuming a 0.5 m overfill (B. Konzelman, pers. comm.*) of the 1.9 m x 21,000 m^2 secondary cell operating capacity. The estimate of $[P_L]$ was calculated from samples of effluent collected during the drawdown period (Appendix II).

Step 17:

The value recommended by Hough, Stansbury and Michalski Limited (1980) has been adopted.

Step 18:

Surficial deposits of the area are primarily glacial and glacial-fluvial in origin (Jenkins, 1970). The deposits generally consist of coarse materials such as sand, gravel, cobble and boulders as well as finer materials such as silts and clays (Ibid). This heterogeneity infers that soil retention coefficients of total phosphorus may differ substantially even on a very localized basis. Therefore, a relatively medial coefficient, that for silty sand, was adopted from the work of Brandes et al (1974).

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* B. Konzelman, Environment Officer, Municipal Waste Water Section, Manitoba Department of Environment and Workplace Safety and Health.

Step 19:

The estimate of campground site units available was derived by Water Standards and Studies following site inspection during summer, fall and winter sampling periods. Factors considered included actual use observed, comments provided by Mr. Dick Edmundson (pers. comm.), facilities available, area available for use and site aesthetics.

Step 20:

An estimate of the mean number of persons per camping unit was not available for either the Shoal Lake area or Manitoba in general. the present estimate was derived from the Hough, Stansbury and Michalski Limited (1980) mean of 4.30 capita years at permanent homes, multiplied by 0.352, the mean Western Region campsite occupancy ratio (Manitoba Natural Resources, 1985). Although the mean campsite ratio may be somewhat high for the Shoal Lake campground, its present use is justified as a way of accounting for loadings due to beach day users and both summer and winter angling activity .

Step 21:

The 1987 season length was estimated on the basis of weekends from May 9 to June 27, and daily thereafter to September 6 (inclusive).

Steps 22 and 23:

Formulae for these calculations were derived from Hough, Stansbury and Michalski Limited (1980).

Step 24:

A count of the cottages was conducted by Water Standards and Studies Section staff.

Step 25:

The absence of specific data for Manitoba necessitated adoption of the values provided by Hough, Stansbury and Michalski Limited (1980).

Step 26:

Residences were defined as occupied homes located within approximatey 250 metres of the lake shore. Homes near to the Town and likely to be connected to the municipal wastewater collection system were excluded. Counts were provided by Water Standards and Studies Section staff.

Step 27:

The values provided by Hough, Stansbury and Michalski Limited (1980) were adopted.

Steps 28, 29, and 30:

Calculations were performed according to formulae presented by Hough, Stansbury and Michalski Limited (1980).

Step 31:

Wind induced turbulence in a shallow lake (<3.0 m deep) can readily suspend surficial sediments, thereby elevating the water

column total phosphorus concentration (De Groot, 1981). De Groot (1981) suggests that over the long term approximately two-thirds of the gross external phosphorus loading settles.

Step 32:

Potential phosphorus loading by groundwater has been excluded from the estimates of total natural supply for several reasons. These include the low phosphorus concentration present in local groundwater*, the significance of groundwater discharge to the hydrology of Shoal Lake is unknown and obvious sources of groundwater discharge (e.g. seeps, springs) do not occur (D. Edmundson, pers. comm.).

Steps 33 and 34:

Calculations were performed according to formulae presented by Hough, Stansbury and Michalski Limited (1980).

3.6 Budget Validation

Budget validity may be assessed either by actual observation or by theoretical means. Since temporal constraints prevented actual measurement of spring phosphorus concentrations over a series of years, actual spring observations could not be used for budget

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* Phosphorus concentrations in water samples collected June 10, 1987 from two private wells (Mr. W. Shwaluk, SE4-17-23, Mr. S. Stetch, Town of Shoal Lake) were both analyzed at <0.010 mg/L.

validation. Theoretical budget validation can be achieved by calculations drawn from the literature. The process involved algebraic manipulation of established formulae in order to isolate the spring phosphorus concentration as a variable. The equation is then solved by substitution of measured values for remaining variables.

The classic equation defining the summer chlorophyll a concentration ([Chla]) to spring total phosphorus concentration ([TP]) relationship in north temperate lakes developed by Dillon and Rigler* (1974) was:

$$\text{Eq. 4a:} \quad \log_{10}[\text{Chla}] = 1.449 \log_{10}[\text{TP}] - 1.136$$

The equation may be manipulated to isolate the [TP] variable as follows:

$$\text{Eq. 4b:} \quad \log_{10}[\text{TP}] = (\log_{10}[\text{Chla}]+1.136)/1.449$$

A second equation defining the [Chla]-[TP] relationship in north temperate, shallow mixed lakes was recently developed by Riley and Prepas (1985)*. This equation was:

$$\text{Eq. 5a:} \quad \log_{10}[\text{Chla}] = 1.251 \log_{10}[\text{TP}] - 0.680$$

The equation may be manipulated to isolate the [TP] variable as follows:

$$\text{Eq. 5b:} \quad \log_{10}[\text{TP}] = (\log_{10}[\text{Chla}]+0.680)/1.251$$

---

* [Chla] and [TP] are expressed as mg/m^3.

Validation using the Dillon and Rigler (1974) and Riley and Prepas (1985) formulae assumes that chlorophyll a production is neither unduly inhibited nor significantly enhanced. Therefore, it is necessary to test the accuracy of chlorophyll a values with respect to interdependent parameters. Carlson's (1977) indices based upon summer values for chlorophyll a, total phosphorus and Secchi disk values were adopted for this purpose. An average of the three indices is calculated and the single occurrence of an index value beyond the limit of $\pm$10% of average was considered arbitrary cause for rejection*. This meant that chlorophyll a concentrations were unsuitable for budget validation where the range of TSI indices exceeded 20% of an average value.

An alternate approach to budget validation considers water column phosphorus concentrations during late winter. This approach is based upon observations of local pothole lakes published by Barica (1977). Generally, he observed that total phosphorus concentrations were greatest prior to spring breakup (i.e. prior to ice melting and consequently prior to the growth of aquatic vegetation and the proliferation of plankton) and that total phosphorus concentrations declined over the summer months as nutrients became trapped within the tissues of the aquatic biota. During fall and winter months, phosphorus was restored to the water column from organic detritus and

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* Justification for arbitrary usage of the "10%" value is based in the statistical axiom that two units of standard deviation correspond to a probability of approximately 95.4%.

the sediments by both aerobic and anaerobic mechanisms. Relevant to the present study, however, was the observation that summer phosphorus concentrations differed from winter concentrations. Furthermore, late winter concentrations better approximated pre-breakup maximums than did summer values. This meant that winter concentrations observed during the present study were better suited for estimation of spring concentrations. This estimation, derived from actual data, could then be used as a check upon the empirically derived prediction of total phosphorus.

Model validation using observed winter values is achieved by first calculating the mean of observed late winter concentrations. An acceptable range is drawn from the defined intent of the sampling program to provide an estimation with a mean standard error of less than 10% of the mean. This intent effectively permits a 20% range (i.e. 2 σ) about the observed mean value. A predicted total phosphorus value within $\pm$10% of the observed mean value therefore indicates validation of the budget.

4.0 RESULTS AND DISCUSSION

Physicochemical data is detailed in Appendix I.

4.1 Trophic Status

Carlson's (1977) indices were plotted (Figure 4) in order to evaluate the trophic status of Shoal Lake. Indices were computed from means of the lake sampling statons only (i.e. WQ984 to WQ988, inclusive). Each of the indices clearly demonstrated that Shoal Lake was a eutrophic waterbody (Figure 4). The phosphorus index (74.7) suggested a hypertrophic state whereas the chlorophyll a index (55.6) suggested moderately eutrophic conditions. The secchi disc index (63.8) lay approximately midway between the two extremes. The implication was that chlorophyll a production was inhibited in terms of the total amount of phosphorus present in the water column. The inference to be drawn was that much of the phosphorus present during summer was in a form that was neither available nor readily convertible for use in primary biological production. Excess phosphorus not involved in chlorophyll a production may have been associated with particulates suspended from the sediments by wind turbulence as per Step 31, Section 3.5.

Vollenweider's (1975) plot (Figure 5) supported the classification of Shoal Lake as a hypertrophic waterbody. The excessive rate of background phosphorus loadings suggested the occurrence of very unstable water quality conditions that might be expected to continue to rapidly deteriorate over time unless ameliorative action was taken.

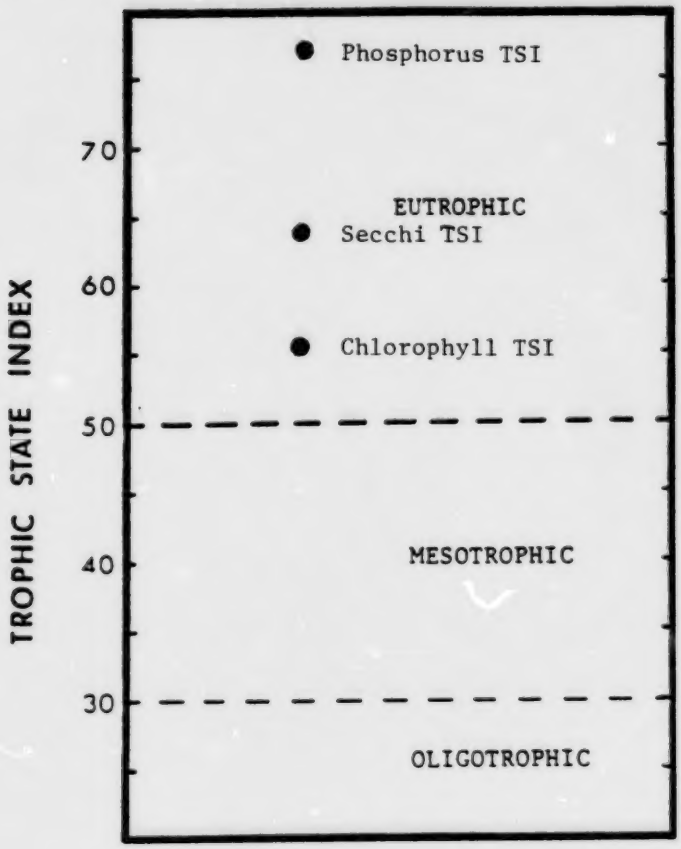

Figure 4. Carlson's (1977) trophic state indices (TSI) for Shoal Lake.

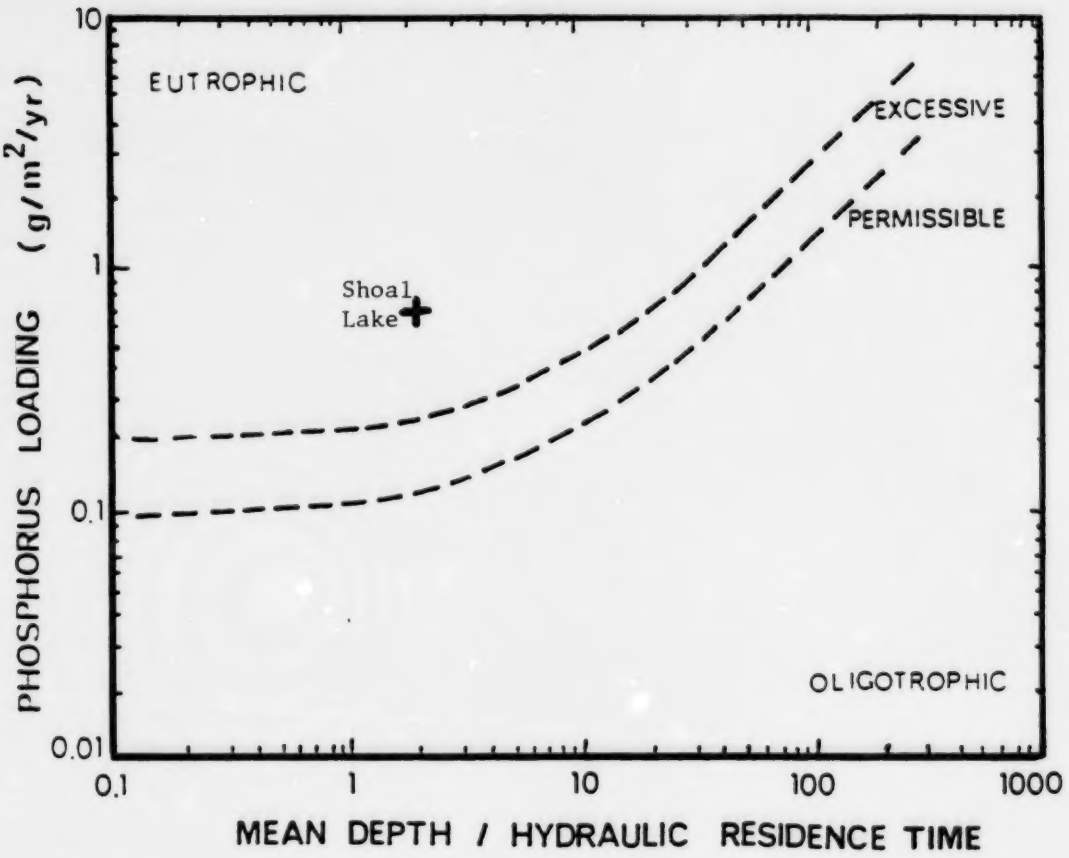

Figure 5: Application of Vollenweider's (1975) trophic state scale to Shoal Lake.

4.2 The Problem Nutrient

As discussed in Section 3.4, nitrogen:phosphorus (N:P) mass ratios greater than the 7.24 to 10.86 range indicated that phosphorus was the limiting nutrient while N:P mass ratios less than the 7.24 to 10.86 range indicated that nitrogen was the limiting nutrient. The N:P mass ratio for Shoal Lake (i.e. stations WQ984 to WQ988, inclusive) was computed at 74.2. This confirms that nitrogen is in abundant supply and that it is phosphorus which limits or controls the growth of algae and macrophytes in Shoal Lake. The relatively high value of the N:P mass ratio for Shoal Lake in comparison to other lakes of the area (e.g. Otter Lake - 33.98, Sandy Lake - 22.81, Stewart Lake 14.39; Beck, 1988) implies an extreme degree of nutrient loading such as might usually be associated with sewage discharges or intensive livestock operations. Adams (1973) had reached a similar conclusion.

4.3 Phosphorus Budget Validation

The phosphorus budget (Table 1) is a calculation process designed to estimate the total phosphorus concentration immediately prior to spring breakup. Validation is essential in order to verify the accuracy of nutrient source quantitations.

As discussed in Section 3.6, mean chlorophyll a concentrations are deemed suitable for validation purposes when the range of TSI indices does not exceed 20% of their average value. The range of TSI indices for Shoal Lake approximated 30% of their average value (range = 19.10, mean = 64.7; per Section 4.1). This confirmed that chlorophyll a production had been inhibited and that the mean

chlorophyll a concentration was unsuitable for evaluating the validity of the Shoal Lake phosphorus budget (Table 1).

Model validation is also possible by using observed lake winter values (Section 3.6). The latest series of winter samples, collected March 17, 1987 (Appendix I), averaged 0.060 mg/L total phosphorus. A mean of 0.060 mg/L means that an acceptable range for estimated spring total phosphorus concentrations would be 0.054 to 0.066 mg/L (i.e. $\pm$10%; Section 3.6). The spring total phosphorus concentration for Shoal Lake had been estimated at 0.055 mg/L (Table 1)*. Because the estimated value lay within the acceptable range, it was inferred that the phosphorus budget for Shoal Lake (i.e. Table 1) was valid.

4.4. Phosphorus Sources

Having inferred the validity of the phosphorus budget (Table 1), phosphorus sources were then itemized and quantified (Table 2).

Internal recycling (i.e. phosphorus released from sediments) accounted for the greater proportion (51.9%) of total phosphorus loading to the water column of Shoal Lake (Table 2). This is a common phenomenon in shallow prairie lakes (Cooke et al, 1972; Jacoby et al, 1982). Sediment release of phosphorus during winter anoxia provided approximately 2.2 times as much long term load to the water column as did wind induced turbulence during the summer (Table 2). However,

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* The value of 0.055 mg/L is equivalent to the value 55.04 mg/m^3 actually cited in Table 1.

Table 2: Shoal Lake Phosphorus Sources and 1987 Contributions*

SOURCE	TOTAL LOADING Volume (Kg/yr)	Proportion(%)	GROSS EXTERNAL LOADING Volume (kg/yr)	Proportion (%)
Drainage Basin	1457	37.3	1457	77.5
Precipitation	195	5.0	195	10.4
Sediments during Anoxia	1402	35.9	N/A	-
Sediments during Winds	626.9	16.0	N/A	-
Sewage Lagoon	200.3	5.1	200.3	10.7
Residences	12.73	0.3	12.73	0.7
Cottages	11.75	0.3	11.75	0.6
Campgrounds	3.86	0.1	3.86	0.2
TOTAL	3909.54 Kg/yr	100.0%	1880.64 Kg/yr	100.1%

* Volumes have been extracted from Table 1 and converted from mg to Kg.

internal recycling itself is a function of gross external loading (De Groot, 1981) in that the greater the phosphorus load entering the lake from outside, the greater the amount of phosphorus available for internal recycling.

Runoff from the drainage basin accounted for approximately 77.5% of the gross external loading to Shoal Lake (Table 2). More than 93% of this load is directly attributable to discharges from the Oak River*. A September 28, 1987 examination of land uses within the upper Oak River watershed (i.e. upstream of Shoal Lake) permitted identification of several likely point sources for excessive phosphorus loadings as well as some areas of potentially significant non point source loadings. The sites having the greatest potential were located within approximately 1.5 kilometres upstream of Shoal Lake. These included (proceeding upstream from Village limits) a heavily manured paddock within approximately 100 m of the Oak River, a horse enclosure adjacent to the stream, a second cattle and horse enclosure adjacent to the stream, a large manure pile adjacent to the stream and what appeared to be a cattle overwintering site directly on and about the Oak River. Each of these sites is of great concern because a single cow passes approximately 5.04 kilograms of phosphorus per year (Appendix III). The proximity of these sites to Shoal Lake permits the release of excessive quantities of animal wastes directly to the Oak River with very little opportunity for reduction of nutrient

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* The value of 93% has been estimated on the basis of proportionate sizes of watershed subdivisions (Step 1, Section 3.5).

content through either sedimentation or assimilation by aquatic plants. Less significant as overall sources, but also of importance in comparison to local background, are pasture lands which straddle the Oak River and its intermittent tributaries. Located several kilometres further upstream, these sites may receive substantial amounts of animal wastes during direct cattle watering and during spring meltwater runoff.

Precipitation, including aerial depositions of particulates and biological material, was estimated to contribute approximately 10.4% of the gross external phosphorus loadings (Table 2). Sources are diverse and may be distant (e.g. any exposed soil surface, smoke particulates) or near (e.g. leaves from shoreline trees).

Approximately 12.2% of the gross external phosphorus loading was directly attributable to human habitation and recreation (Table 2). The bulk of this was attributable to discharges from the Village sewage lagoon. Rural residences, cottages and campgrounds contributed approximately 1.5% of the gross external phosphorus load (Table 2) to Shoal Lake.

5.0 CONCLUSIONS

It was concluded that:

1. Shoal Lake is a hypertrophic waterbody with an excessive rate of external phosphorus loading.
2. Phosphorus is the problem nutrient which controls algae and macrophyte production in Shoal Lake.
3. A valid phosphorus budget was developed for Shoal Lake.
4. Internal recycling from lake sediments, a phenomenon accelerated by the rate of gross external loading, accounted for approximately 51.9% of the total phosphorus loading to the water column of Shoal Lake. Phosphorus release from sediments during anoxia was estimated at 1402 Kg per year and effective phosphorus release from sediments due to wind induced turbulence was estimated at approximately 626.9 Kg per year.
5. Runoff from the drainage basin, estimated at 1457 Kg per year, accounted for approximately 77.5% of gross external loading. Excessive phosphorus discharges were attributed primarily to concentrated livestock holdings located along the Oak River and within approximately 1.5 kilometres upstream of Shoal Lake and, secondarily to pastures which straddled the Oak River at sites several kilometres further upstream.
6. Discharges from the Village of Shoal Lake sewage lagoon accounted for approximately 10.7% (200.8 Kg) of the gross external phosphorus loading to Shoal Lake.

7. Approximately 195 Kg, or 10.4% of gross external phosphorus loading, was attributable to precipitation, dust and other materials aerially deposited.

8. Phosphorus loadings attributable to rural residences, cottages and campgrounds were estimated at approximately 1.5% of the gross external load.

6.0 ACKNOWLEDGEMENTS

Credit for initiating the actions which resulted in the present study properly belongs to Mr. Dick Edmundson, Reeve, and members of the Council of the R.M. of Shoal Lake. Their foresight, concern and attention is gratefully acknowledged. Support, cooperation, assistance and interest by Councils of both the R.M. and of the Village during the actual study period was also greatly appreciated. We are particularly indebted to Mr. Dick Edmundson and Mr. Roy Garlick for their conscientious and diligent efforts at sample collection. The study would not have been possible without their contributions. Sample analyses by staff of the W.M. Ward Technical Services Laboratory is also gratefully acknowledged.

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STATION WQ0982, SOURCE - SHOAL LAKE
SAMPLING LOCATION - INLET LATITUDE 50:26 LONGITUDE 100:36

DATE	COND US/CM	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L
87 03 17	4720.0	7.35	240.	293.	0.0	0.0	90.80	41.40	396.0
87 04 04	674.0	7.35	130.	168.	0.0	0.0	48.00	27.80	234.0
87 04 12	381.0	7.60	106.	129.	0.0	0.0	31.00	19.20	157.0
87 04 26	600.0	7.75	172.	210.	0.0	0.0	51.40	34.80	272.0
87 05 06	722.0	7.95	214.	261.	0.0	0.0	58.90	45.50	335.0
87 05 18	774.0	7.75	250.	305.	0.0	0.0	67.90	50.10	376.0
87 05 26	810.0	8.00	262.	320.	0.0	0.0	66.20	48.60	365.0
87 06 03	844.0	7.95	284.	346.	0.0	0.0	80.80	59.10	446.0
87 06 11	832.0	7.85	288.	351.	0.0	0.0	74.20	54.80	412.0
87 06 18	886.0	7.85	296.	361.	0.0	0.0	74.10	56.20	416.0
87 06 23	828.0	8.10	300.	366.	0.0	0.0	69.40	54.60	399.0
87 07 01	809.0	8.05	282.	344.	0.0	0.0	67.10	51.90	381.0
87 07 09	872.0	8.00	316.	386.	0.0	0.0	67.00	55.30	396.0
87 07 15	899.0	8.35	338.	407.	2.4	0.0	69.60	60.70	425.0
87 07 22	891.0	8.00	324.	395.	0.0	0.0	66.20	56.40	398.0
87 07 29	952.0	8.05	350.	427.	0.0	0.0	77.50	62.90	452.0
87 08 05	917.0	8.45	318.	378.	4.8	0.0	70.90	58.70	419.0
87 08 12	867.0	8.10	278.	339.	0.0	0.0	62.60	52.60	373.0
87 08 19	995.0	8.25	354.	432.	0.0	0.0	62.60	62.50	414.0
87 08 25	1030.0	8.20	374.	456.	0.0	0.0	67.00	60.80	418.0
87 09 02	1010.0	8.05	370.	451.	0.0	0.0	72.50	70.30	470.0
87 09 08	1010.0	8.35	354.	427.	2.4	0.0	68.60	68.70	455.0
87 09 13	1090.0	8.10	378.	461.	0.0	0.0	70.20	69.90	463.0
87 09 29	963.0	8.30	304.	371.	0.0	0.0	61.70	64.80	421.0
87 11 05	1540.0	8.30	354.	432.	0.0	0.0	78.70	62.50	454.0

STATION WQ0982, SOURCE - SHOAL LAKE
SAMPLING LOCATION - INLET LATITUDE 50:26 LONGITUDE 100:36

DATE	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L
87 03 17	1.24	0.89	47.00	760.00	4.7	34.00	11.2	4.25	1.300
87 04 04	0.53	0.42	8.50	49.80	---	12.00	10.8	1.75	---
87 04 12	0.03	0.20	10.00	14.50	---	3.50	10.1	0.85	---
87 04 26	0.04	0.13	14.00	24.50	---	1.30	7.8	1.20	---
87 05 06	0.04	0.11	16.00	28.10	8.9	0.71	4.0	1.25	---
87 05 18	0.06	0.15	18.00	28.80	7.5	1.90	4.4	1.30	---
87 05 26	0.15	0.19	19.00	25.90	7.0	2.90	4.6	2.10	0.040
87 06 03	0.24	0.31	18.50	31.50	8.0	2.90	8.1	1.65	0.019
87 06 11	0.22	0.26	19.50	31.40	6.1	2.10	9.7	1.75	0.050
87 06 18	0.14	0.18	20.00	36.20	5.8	2.20	10.7	1.95	0.043
87 06 23	0.10	0.16	17.00	31.70	6.4	4.50	11.7	1.80	0.048
87 07 01	0.19	0.58	19.00	31.40	5.9	21.00	10.8	1.85	0.125
87 07 09	0.36	0.43	20.50	38.10	5.2	9.10	10.3	1.85	0.063
87 07 15	0.27	0.32	21.00	40.90	9.3	3.40	10.4	2.00	0.040
87 07 22	0.32	0.23	19.00	43.10	5.5	5.80	12.3	2.10	0.040
87 07 29	0.48	0.27	19.00	44.80	6.9	3.90	11.0	2.00	0.036
87 08 05	0.28	0.22	18.50	51.50	10.4	2.80	3.4	1.75	0.007
87 08 12	0.48	0.44	16.00	48.50	8.6	6.10	4.4	1.50	0.026
87 08 19	0.45	0.42	19.50	55.40	8.9	12.00	3.5	2.10	0.015
87 08 25	0.58	0.60	20.50	57.10	6.0	21.00	1.6	2.50	0.022
87 09 02	0.62	0.41	21.50	66.30	4.7	12.00	1.3	2.50	0.042
87 09 08	0.54	0.48	22.00	66.20	8.4	14.00	0.7	2.30	0.013
87 09 13	0.72	0.79	22.00	70.40	5.4	20.00	1.0	2.70	0.074
87 09 29	0.81	1.11	18.50	65.50	9.3	12.00	2.3	2.85	0.018
87 11 05	0.32	0.54	16.00	176.00	11.6	11.00	1.5	2.05	0.011

STATION WQ0982, SOURCE - SHOAL LAKE
SAMPLING LOCATION - INLET LATITUDE 50:26 LONGITUDE 100:36

DATE	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	SULPHATE MG(SO4)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
87 03 17	1.020	0.3450	1500.00	200.0	---	---	0.10
87 04 04	1.500	0.4400	16.00	188.0	---	---	0.30
87 04 12	0.210	0.2500	7.00	80.0	---	---	0.20
87 04 26	0.020	0.0600	6.00	132.0	---	---	0.20
87 05 06	0.020	0.0800	8.00	155.0	1.0 L	0.70 G	0.35
87 05 18	0.010	0.1400	5.00	170.0	1.0 L	0.60 G	0.30
87 05 26	0.020	0.1400	7.50	180.0	1.0 L	0.60 G	0.30
87 06 03	0.020	0.2400	10.00	170.0	2.5	---	---
87 06 11	0.020	0.2450	10.00	168.0	5.0	0.50 G	0.00
87 06 18	0.020	0.3400	8.00	185.0	1.0	0.50 G	0.25
87 06 23	0.010	0.3750	8.00	148.0	1.0 L	0.50 G	0.25
87 07 01	0.560	0.4900	10.00	140.0	2.5	0.50 G	0.25
87 07 09	0.020	0.3350	10.00	150.0	1.5	0.50 G	0.25
87 07 15	0.010 L	0.3100	10.00	158.0	2.5	0.50 G	0.25
87 07 22	0.020	0.4100	13.00	153.0	2.0	0.50 G	0.25
87 07 29	0.010 L	0.3550	18.00	182.0	9.5	0.50 G	0.25
87 08 05	0.010 L	0.2500	25.00	180.0	6.0	0.50 G	0.25
87 08 12	0.180	0.2550	28.00	168.0	10.5	0.50 G	0.25
87 08 19	0.010 L	0.2350	25.00	180.0	7.0	0.50 G	0.25
87 08 25	0.010 L	0.3100	28.00	205.0	5.0	0.30 G	0.15
87 09 02	0.010 L	0.3050	30.00	190.0	8.0	0.30 G	0.15
87 09 08	0.010 L	0.2850	25.00	188.0	1.5	0.20 G	0.10
87 09 13	0.010 L	0.3550	30.00	190.0	1.0 L	0.20 G	0.10
87 09 29	0.010	0.4000	33.00	198.0	---	---	0.10
87 11 05	0.010 L	0.2250	95.00	380.0	---	---	0.10

STATION WQ0983, SOURCE - SHOAL LAKE
SAMPLING LOCATION - NORTH POND LATITUDE 50:26 LONGITUDE 100:36

DATE	COND US/CM	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L
87 03 17	1640.0	7.60	486.	593.	0.0	0.0	104.00	68.20	540.0
87 05 06	696.0	8.05	204.	249.	0.0	0.0	57.40	42.70	319.0
87 05 18	767.0	8.15	242.	295.	0.0	0.0	69.50	48.90	375.0
87 05 26	783.0	8.45	256.	303.	4.8	0.0	67.80	46.00	359.0
87 06 03	810.0	8.45	263.	309.	6.0	0.0	78.00	55.90	424.0
87 06 11	803.0	8.45	258.	305.	4.8	0.0	72.30	53.20	400.0
87 06 18	833.0	8.30	264.	322.	0.0	0.0	68.60	51.60	384.0
87 06 23	821.0	8.50	294.	320.	7.2	0.0	69.80	52.30	390.0
87 07 01	872.0	8.35	288.	342.	4.8	0.0	72.50	53.70	403.0
87 07 09	852.0	8.55	298.	339.	12.0	0.0	71.20	53.20	397.0
87 07 15	868.0	8.35	300.	361.	2.4	0.0	73.30	58.40	423.0
87 07 22	844.0	8.50	298.	349.	7.2	0.0	70.40	52.70	393.0
87 07 29	857.0	8.40	294.	354.	2.4	0.0	73.00	56.60	416.0
87 08 05	859.0	8.40	296.	351.	4.8	0.0	68.90	55.20	400.0
87 08 12	838.0	8.45	296.	346.	7.2	0.0	63.70	54.30	383.0
87 08 19	851.0	8.55	302.	349.	9.6	0.0	63.60	53.10	378.0
87 08 25	851.0	8.65	300.	337.	14.4	0.0	64.30	52.90	378.0
87 09 02	848.0	8.45	300.	356.	4.8	0.0	70.10	58.90	417.0
87 09 08	845.0	8.50	302.	349.	9.6	0.0	69.60	57.20	410.0
87 09 13	885.0	8.35	304.	366.	2.4	0.0	69.20	57.60	410.0
87 09 29	874.0	8.50	294.	339.	9.6	0.0	64.40	60.20	409.0
87 11 05	919.0	8.50	296.	332.	14.4	0.0	82.80	60.20	455.0
88 02 24	1950.0	7.90	606.	739.	0.0	0.0	158.00	118.00	880.0

STATION MQ0983, SOURCE - SHOAL LAKE
SAMPLING LOCATION - NORTH POND LATITUDE 50:26 LONGITUDE 100:36

DATE	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L
87 03 17	0.70	0.49	23.00	123.00	---	9.00	33.0	6.05	3.050
87 05 06	0.05	0.11	16.00	28.10	8.6	1.80	5.6	1.20	---
87 05 18	0.08	0.14	17.50	30.30	7.8	2.80	6.0	1.55	---
87 05 26	0.08	0.10	18.50	26.10	10.4	2.00	6.2	1.70	0.020 L
87 06 03	0.18	0.21	18.00	34.20	8.5	7.50	7.4	2.10	0.037
87 06 11	0.20	0.28	18.50	35.20	7.2	9.50	8.9	2.25	0.335
87 06 18	0.18	0.26	18.00	35.40	6.4	9.30	8.9	2.15	0.105
87 06 23	0.18	0.26	16.50	37.70	8.7	3.80	11.2	1.80	0.038
87 07 01	0.19	0.25	19.50	38.50	5.7	4.20	14.6	1.85	0.050
87 07 09	0.19	0.19	20.00	40.30	7.8	4.30	15.5	1.95	0.064
87 07 15	0.18	0.21	19.00	40.70	5.2	4.10	15.5	1.90	0.030
87 07 22	0.19	0.26	18.50	39.30	7.4	6.00	15.8	2.10	0.013
87 07 29	0.19	0.21	19.00	40.20	7.7	5.00	14.4	2.00	0.014
87 08 05	0.24	0.22	20.00	42.90	7.5	5.40	14.2	1.95	0.008
87 08 12	0.25	0.26	20.50	41.90	6.1	7.00	12.7	1.85	0.010
87 08 19	0.71	0.35	19.50	41.20	8.2	12.00	12.4	1.90	0.015
87 08 25	0.24	0.19	20.50	41.60	9.9	4.60	12.0	2.10	0.013
87 09 02	7.36	0.21	20.50	46.30	6.9	8.60	12.5	2.00	0.039
87 09 08	0.39	0.47	20.00	46.40	8.0	9.00	12.7	2.00	0.011
87 09 13	0.36	0.39	20.00	48.10	6.8	10.00	13.6	2.15	0.047
87 09 29	0.15	0.22	20.00	49.10	9.3	3.40	13.7	2.10	0.006
87 11 05	0.06	0.20	18.00	49.20	11.4	4.20	13.9	1.65	0.007
88 02 24	0.34	0.21	34.50	115.00	3.9	4.70	29.0	3.35	0.165

STATION WQ0983, SOURCE - SHOAL LAKE
SAMPLING LOCATION - NORTH POND LATITUDE 50:26 LONGITUDE 100:36

DATE	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	SULPHATE MG(SO4)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
87 03 17	0.020	0.0850	51.00	396.0	---	---	0.30
87 05 06	0.010 L	0.0750	8.00	155.0	1.5	1.40	0.80
87 05 18	0.010	0.1100	5.00	175.0	4.5	1.00	0.50
87 05 26	0.010 L	0.1150	7.50	175.0	3.5	1.00	1.30
87 06 03	0.010 L	0.1300	10.00	182.0	9.5	0.60	1.20
87 06 11	0.010	0.1200	10.00	182.0	9.5	0.50	0.30
87 06 18	0.020	0.1700	8.00	188.0	5.0	0.50	0.50
87 06 23	0.010 L	0.2300	13.00	182.0	4.5	0.75	0.70
87 07 01	0.010 L	0.1850	13.00	180.0	2.0	0.75	1.10
87 07 09	0.010 L	0.1650	13.00	175.0	3.5	0.75	1.10
87 07 15	0.030	0.1500	13.00	178.0	2.5	0.75	0.60
87 07 22	0.010 L	0.1750	13.00	178.0	1.0	0.75	0.20
87 07 29	0.010 L	0.2250	13.00	178.0	5.5	0.90	1.50
87 08 05	0.010 L	0.2200	15.00	172.0	5.5	0.75	0.10
87 08 12	0.010 L	0.2050	13.00	170.0	7.5	0.75	1.30
87 08 19	0.010 L	0.1900	13.00	180.0	8.0	0.30	1.00
87 08 25	0.010	0.1500	13.00	182.0	2.5	0.60	1.40
87 09 02	0.010 L	0.1850	13.00	115.0	3.5	0.30	0.10
87 09 08	0.010 L	0.1750	13.00	180.0	3.5	0.30	1.10
87 09 13	0.010	0.1650	13.00	178.0	3.5	0.40	1.10
87 09 29	0.010	0.1400	13.00	198.0	---	0.50	0.60
87 11 05	0.010 L	0.0850	15.00	232.0	---	---	0.10
88 02 24	0.070	0.1450	35.00	516.0	---	---	1.10

STATION WQ0984, SOURCE - SHOAL LAKE
SAMPLING LOCATION - SITE 2 LATITUDE 50:26 LONGITUDE 100:36

DATE	COND US/CM	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L
87 03 17	1300.0	7.95	264.	322.	0.0	0.0	49.20	72.30	420.0
87 05 06	803.0	8.60	188.	220.	4.8	0.0	44.20	51.80	324.0
87 05 18	862.0	8.45	196.	234.	2.4	0.0	47.60	53.20	338.0
87 05 26	864.0	8.70	200.	225.	9.6	0.0	46.20	50.00	322.0
87 06 03	886.0	8.55	194.	227.	4.8	0.0	47.60	53.50	339.0
87 06 11	864.0	8.55	194.	217.	9.6	0.0	47.70	54.80	345.0
87 06 19	886.0	8.85	188.	200.	14.4	0.0	44.40	53.70	332.0
87 06 23	854.0	8.95	186.	188.	19.2	0.0	44.20	54.10	332.0
87 07 01	872.0	8.95	186.	188.	19.2	0.0	43.80	54.30	332.0
87 07 09	889.0	9.00	186.	183.	21.6	0.0	43.50	55.80	339.0
87 07 15	922.0	8.90	194.	197.	19.2	0.0	43.90	59.30	354.0
87 07 22	914.0	9.00	192.	190.	21.6	0.0	40.90	53.40	322.0
87 07 29	872.0	8.85	180.	190.	14.4	0.0	40.20	56.50	333.0
87 08 05	906.0	8.75	188.	205.	12.0	0.0	42.50	56.40	338.0
87 08 12	876.0	8.95	182.	183.	19.2	0.0	38.60	55.00	323.0
87 08 19	891.0	9.15	186.	154.	36.0	0.0	37.90	53.70	316.0
87 08 25	863.0	9.15	188.	171.	28.8	0.0	38.70	54.00	319.0
87 09 02	859.0	9.05	182.	168.	26.4	0.0	38.30	60.00	343.0
87 09 08	849.0	9.25	176.	156.	28.8	0.0	38.40	57.20	331.0
87 09 13	921.0	9.15	178.	163.	26.4	0.0	38.00	59.10	338.0
87 09 29	903.0	8.90	178.	178.	19.2	0.0	37.40	59.80	340.0
87 11 05	919.0	8.50	188.	215.	7.2	0.0	44.50	56.90	345.0
88 02 24	1370.0	7.80	278.	339.	0.0	0.0	60.30	82.40	490.0

STATION WQ0984, SOURCE - SHOAL LAKE
SAMPLING LOCATION - SITE 2 LATITUDE 50:26 LONGITUDE 100:36

DATE	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L
87 03 17	0.10	0.08	29.50	94.00	1.4	0.87	8.4	3.70	0.665
87 05 06	0.05	0.04	18.00	56.90	10.6	2.10	7.2	1.55	---
87 05 18	0.09	0.04	18.50	59.80	8.2	3.70	3.7	1.95	---
87 05 26	0.07	0.04	19.00	55.60	9.7	3.10	2.0	1.85	0.025
87 06 03	0.07	0.10	18.50	60.10	9.3	8.60	1.0	2.00	0.006
87 06 11	0.08	0.09	19.50	61.80	8.9	4.30	1.0	2.50	0.280
87 06 19	0.06	0.09	19.00	62.40	9.3	4.40	1.6	2.50	0.016
87 06 23	0.07	0.07	18.00	61.60	9.5	4.60	1.8	2.20	0.015
87 07 01	0.10	0.05	19.00	64.90	9.0	43.00	2.8	2.20	0.006
87 07 09	0.12	0.04	20.50	73.60	9.2	3.30	2.6	2.75	0.078
87 07 15	0.12	0.03	20.00	73.20	9.1	5.20	2.5	2.65	0.070
87 07 22	0.13	0.03	20.00	68.70	9.4	3.20	1.0	3.00	0.022
87 07 29	0.12	0.05	18.00	67.70	5.5	4.00	0.3	2.05	0.006
87 08 05	0.16	0.05	20.50	70.30	7.5	3.40	1.6	2.45	0.005
87 08 12	0.14	0.04	21.00	67.10	8.5	6.30	1.9	2.75	0.010
87 08 19	1.64	0.05	19.50	65.60	10.4	6.00	1.7	2.75	0.011
87 08 25	0.15	0.04	19.50	65.20	9.0	11.00	1.6	2.50	0.004
87 09 02	0.15	0.04	21.50	70.60	9.2	6.50	1.3	2.70	0.008
87 09 08	0.18	0.05	20.50	69.80	11.2	4.30	0.5	2.85	0.004
87 09 13	0.15	0.05	20.00	79.20	9.5	8.50	0.2 L	2.65	0.013
87 09 29	0.06	0.06	21.00	75.70	9.0	4.80	0.2 L	2.95	0.027
87 11 05	0.06	0.08	19.50	72.00	11.3	5.00	0.2 L	2.40	0.490
88 02 24	0.16	0.20	30.00	101.00	4.4	1.80	1.5	4.50	1.500

STATION WQ0984, SOURCE - SHOAL LAKE
SAMPLING LOCATION - SITE 2 LATITUDE 50:26 LONGITUDE 100:36

DATE	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	SULPHATE MG(SO4)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
87 03 17	0.020	0.0800	45.00	390.0	---	---	0.80
87 05 06	0.010 L	0.0800	22.00	210.0	4.0	1.10	0.20
87 05 18	0.010 L	0.1200	25.00	235.0	4.0	1.00	0.40
87 05 26	0.010	0.1000	27.00	232.0	10.5	1.30	0.20
87 06 03	0.010 L	0.1100	25.00	235.0	7.5	0.80	0.20
87 06 11	0.010	0.1450	25.00	235.0	12.3	0.75	0.70
87 06 19	0.010 L	0.2100	25.00	250.0	18.8	0.50	0.70
87 06 23	0.010 L	0.1600	28.00	248.0	10.5	0.60	0.20
87 07 01	0.010 L	0.1500	28.00	248.0	21.0	0.80	0.44
87 07 09	0.010 L	0.2600	18.00	255.0	24.0	0.50	0.00
87 07 15	0.010 L	0.1250	33.00	260.0	14.0	0.75	0.40
87 07 22	0.010 L	0.1800	30.00	250.0	10.0	0.50	0.80
87 07 29	0.010 L	0.0900	53.00	262.0	5.0	1.00	0.10
87 08 05	0.010 L	0.1350	30.00	255.0	15.0	0.75	0.50
87 08 12	0.010 L	0.1450	28.00	250.0	22.5	0.50	0.70
87 08 19	0.010 L	0.1500	30.00	260.0	17.0	0.50	0.70
87 08 25	0.010 L	0.1200	28.00	262.0	9.5	0.50	0.00
87 09 02	0.010 L	0.1350	30.00	262.0	7.0	0.50	0.00
87 09 08	0.010	0.1500	33.00	260.0	9.0	0.50	1.00
87 09 13	0.010 L	0.1300	35.00	250.0	8.0	0.50	0.80
87 09 29	0.010	0.1450	30.00	275.0	---	0.60	0.40
87 11 05	0.020	0.1200	33.00	276.0	---	---	0.60
88 02 24	0.080	0.0850	48.00	396.0	---	---	0.30

STATION WQ0985, SOURCE - SHOAL LAKE
SAMPLING LOCATION - SITE 3 LATITUDE 50:25 LONGITUDE 100:36

DATE	COND US/CM	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L
87 03 17	1260.0	7.90	260.	317.	0.0	0.0	49.30	71.90	417.0
87 05 06	829.0	8.65	184.	210.	7.2	0.0	41.50	52.50	320.0
87 05 18	848.0	8.55	188.	220.	4.8	0.0	44.80	53.70	333.0
87 05 26	869.0	8.70	190.	212.	9.6	0.0	40.80	49.20	304.0
87 06 03	863.0	8.45	192.	229.	2.4	0.0	46.20	53.40	336.0
87 06 11	901.0	8.70	194.	222.	7.2	0.0	47.50	55.20	346.0
87 06 19	876.0	8.75	190.	212.	9.6	0.0	46.20	54.20	338.0
87 06 23	885.0	9.00	186.	183.	21.6	0.0	43.90	54.30	333.0
87 07 01	869.0	9.05	186.	173.	26.4	0.0	42.40	52.90	324.0
87 07 09	886.0	9.05	190.	178.	26.4	0.0	44.50	55.20	338.0
87 07 15	922.0	8.90	194.	198.	19.2	0.0	44.00	59.60	355.0
87 07 22	905.0	9.10	190.	183.	24.0	0.0	41.40	53.30	323.0
87 07 29	837.0	9.15	168.	156.	24.0	0.0	37.40	57.00	328.0
87 08 05	906.0	8.75	182.	198.	12.0	0.0	42.00	56.60	338.0
87 08 12	869.0	8.90	180.	185.	16.8	0.0	37.80	54.60	319.0
87 08 19	887.0	9.20	188.	166.	31.2	0.0	38.20	54.10	318.0
87 08 25	863.0	9.25	178.	144.	36.0	0.0	37.20	52.20	310.0
87 09 02	858.0	9.10	170.	154.	26.4	0.0	36.30	58.10	330.0
87 09 08	866.0	9.20	172.	156.	26.4	0.0	37.90	56.50	328.0
87 09 13	881.0	9.15	174.	159.	26.4	0.0	36.90	57.60	330.0
87 09 29	898.0	9.00	182.	168.	26.4	0.0	37.80	59.70	340.0
87 11 05	882.0	8.55	188.	210.	9.6	0.0	43.90	56.50	342.0
88 02 24	1340.0	7.80	276.	337.	0.0	0.0	59.50	80.80	481.0

STATION WQ0985, SOURCE - SHOAL LAKE
SAMPLING LOCATION - SITE 3 LATITUDE 50:25 LONGITUDE 100:36

DATE	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L
87 03 17	0.09	0.08	29.00	93.40	1.5	1.40	8.2	3.50	0.770
87 05 06	0.05	0.03	18.50	59.70	10.1	1.90	6.8	1.80	---
87 05 18	0.08	0.03	18.50	59.10	8.8	4.10	3.9	1.95	---
87 05 26	0.07	0.04	19.00	56.10	10.5	3.10	1.4	1.95	0.020
87 06 03	0.12	0.08	18.50	60.10	8.5	6.90	1.2	2.00	0.039
87 06 11	0.09	0.08	19.50	62.70	7.7	5.60	1.0	2.25	0.175
87 06 19	0.07	0.10	19.00	63.40	7.7	5.60	1.6	2.60	0.013
87 06 23	0.07	0.06	18.50	62.50	9.4	3.50	1.9	2.25	0.032
87 07 01	1.63	0.06	20.50	63.10	8.9	4.30	2.6	2.40	0.004
87 07 09	0.13	0.05	20.50	68.10	9.2	2.60	2.1	2.40	0.118
87 07 15	0.14	0.03	20.50	72.80	9.2	4.10	2.0	2.55	0.050
87 07 22	0.14	0.04	20.50	65.60	11.4	3.10	0.3	2.70	0.034
87 07 29	0.08	0.05	18.00	64.10	13.4	3.80	0.3	2.10	0.004
87 08 05	0.16	0.04	20.50	70.20	7.7	4.20	1.5	2.65	0.004
87 08 12	0.15	0.04	21.00	66.50	8.7	4.50	1.8	2.90	0.005
87 08 19	0.21	0.05	19.50	65.60	10.8	6.60	1.5	2.85	0.008
87 08 25	0.11	0.04	20.00	64.00	12.7	8.10	1.3	2.85	0.005
87 09 02	0.15	0.05	21.50	72.10	9.1	3.70	1.0	2.90	0.008
87 09 08	0.14	0.05	21.00	70.50	10.7	5.10	0.2 L	2.80	0.005
87 09 13	0.14	0.04	21.00	72.40	9.5	7.60	0.3	2.80	0.003
87 09 29	0.06	0.06	21.00	74.70	9.4	6.50	0.2 L	2.95	0.021
87 11 05	0.06	0.08	20.00	69.30	12.2	5.30	0.2 L	2.50	0.495
88 02 24	0.14	0.07	29.50	98.90	1.9	1.72	1.6	3.90	1.600

STATION MQ0985, SOURCE - SHOAL LAKE
SAMPLING LOCATION - SITE 3 LATITUDE 50:25 LONGITUDE 100:36

DATE	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	SULPHATE MG(SO4)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
87 03 17	0.020	0.0750	44.00	375.0	---	---	0.00
87 05 06	0.010 L	0.0850	25.00	222.0	5.5	1.20	1.60
87 05 18	0.010 L	0.1450	25.00	238.0	5.0	1.00	2.20
87 05 26	0.010	0.0950	27.50	240.0	6.0	1.50	1.60
87 06 03	0.010 L	0.1050	28.00	240.0	6.5	0.90	1.70
87 06 11	0.010 L	0.1400	25.00	240.0	10.0	1.00	1.70
87 06 19	0.010 L	0.1550	25.00	250.0	14.0	0.60	1.10
87 06 23	0.010 L	0.1900	30.00	250.0	12.5	0.60	1.10
87 07 01	0.010 L	0.1600	30.00	253.0	23.0	0.60	0.30
87 07 09	0.010 L	0.1450	18.00	250.0	12.5	0.60	2.50
87 07 15	0.010 L	0.1250	33.00	265.0	10.5	0.75	0.00
87 07 22	0.030	0.1550	30.00	253.0	12.5	0.60	1.90
87 07 29	0.010 L	0.1000	33.00	260.0	12.0	0.75	1.40
87 08 05	0.020	0.1350	30.00	255.0	21.0	0.75	1.40
87 08 12	0.010	0.1650	28.00	252.0	27.0	0.50	0.50
87 08 19	0.010 L	0.1500	30.00	255.0	15.0	0.50	1.00
87 08 25	0.010 L	0.1450	33.00	265.0	9.5	0.50	1.60
87 09 02	0.010 L	0.1450	30.00	262.0	13.5	0.50	0.50
87 09 08	0.010 L	0.1500	33.00	260.0	10.0	0.40	0.00
87 09 13	0.010 L	0.1250	33.00	260.0	8.5	0.60	0.80
87 09 29	0.010	0.1400	30.00	272.0	---	0.50	2.10
87 11 05	0.020	0.0750	33.00	272.0	---	1.05	1.90
88 02 24	0.050	0.0600	48.00	390.0	---	---	0.30

STATION WQ0986, SOURCE - SHOAL LAKE
SAMPLING LOCATION - SITE 4 LATITUDE 50:24 LONGITUDE 100:37

DATE	COND US/CM	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L
87 03 17	1250.0	7.85	248.	303.	0.0	0.0	49.90	72.70	423.0
87 05 06	856.0	8.65	178.	198.	9.6	0.0	39.60	56.20	331.0
87 05 18	862.0	8.55	184.	210.	7.2	0.0	42.90	54.60	332.0
87 05 26	864.0	8.75	186.	203.	12.0	0.0	40.80	49.50	304.0
87 06 03	874.0	8.50	190.	227.	2.4	0.0	43.20	51.90	322.0
87 06 11	874.0	8.50	194.	232.	2.4	0.0	46.10	55.50	342.0
87 06 19	908.0	8.15	214.	261.	0.0	0.0	77.50	55.70	423.0
87 06 23	887.0	8.65	188.	215.	7.2	0.0	46.30	54.30	340.0
87 07 01	888.0	8.90	194.	203.	16.8	0.0	44.80	53.20	331.0
87 07 09	876.0	9.00	192.	190.	21.6	0.0	45.40	54.60	338.0
87 07 15	889.0	8.90	194.	198.	19.2	0.0	45.20	57.10	348.0
87 07 22	900.0	9.05	192.	181.	26.4	0.0	41.20	52.30	319.0
87 07 29	842.0	9.25	168.	142.	31.2	0.0	36.90	56.30	324.0
87 08 05	887.0	8.85	176.	181.	16.8	0.0	38.60	55.50	325.0
87 08 12	843.0	9.00	180.	181.	19.2	0.0	37.40	55.20	321.0
87 08 19	885.0	9.15	178.	163.	26.4	0.0	37.00	54.00	31.5
87 08 25	853.0	9.15	180.	151.	33.6	0.0	37.90	53.30	315.0
87 09 02	858.0	8.85	178.	163.	26.4	0.0	36.80	57.10	328.0
87 09 08	871.0	9.20	176.	161.	26.4	0.0	38.80	56.60	330.0
87 09 13	876.0	9.10	176.	166.	24.0	0.0	38.00	57.50	332.0
87 09 29	889.0	8.90	178.	178.	19.2	0.0	37.60	58.80	337.0
87 11 05	881.0	8.00	182.	222.	0.0	0.0	43.50	56.20	340.0
88 02 24	1320.0	7.75	270.	329.	0.0	0.0	58.30	80.10	476.0

STATION WQ0986, SOURCE - SHOAL LAKE
SAMPLING LOCATION - SITE 4 LATITUDE 50:24 LONGITUDE 100:37

DATE	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L
87 03 17	0.09	0.02	27.00	95.40	0.1 L	0.93	8.3	3.40	0.820
87 05 06	0.06	0.03	18.50	67.60	1.0	2.00	6.4	1.95	---
87 05 18	0.07	0.03	18.50	60.90	8.3	3.60	3.9	2.10	---
87 05 26	0.07	0.03	19.00	56.70	10.7	6.30	1.8	2.10	0.020 L
87 06 03	0.09	0.06	18.50	59.00	7.9	6.40	1.2	2.05	0.105
87 06 11	0.10	0.06	19.50	62.90	8.1	2.30	1.1	2.35	0.230
87 06 19	0.27	1.33	20.00	62.60	2.4	85.00	2.2	5.10	0.320
87 06 23	0.13	0.06	16.00	62.20	6.3	4.60	2.0	2.30	0.115
87 07 01	0.14	0.05	20.50	63.30	8.0	7.50	2.4	2.30	0.003
87 07 09	0.11	0.05	20.50	65.40	9.9	2.30	0.9	2.40	0.044
87 07 15	0.15	0.04	20.50	67.40	8.6	3.50	1.0	2.55	0.090
87 07 22	0.11	0.03	19.00	63.80	9.8	8.40	0.4	2.55	0.018
87 07 29	0.07	0.05	18.00	64.20	13.5	12.00	0.2	2.20	0.008
87 08 05	0.11	0.04	20.00	67.50	2.5	2.00	1.5	2.30	0.029
87 08 12	0.12	0.03	20.50	66.50	8.7	5.50	1.6	2.75	0.006
87 08 19	0.14	0.04	19.50	64.70	9.7	3.80	1.4	2.65	0.005
87 08 25	0.12	0.05	20.00	63.80	10.8	8.30	0.9	3.00	0.006
87 09 02	0.17	0.04	21.50	68.30	9.2	4.40	0.9	2.70	0.010
87 09 08	0.17	0.05	21.00	69.80	10.2	7.50	0.4	2.95	0.004
87 09 13	0.18	0.04	21.50	71.30	10.0	7.70	0.2	3.00	0.007
87 09 29	0.08	0.06	21.00	70.70	8.3	5.00	0.2 L	2.95	0.122
87 11 05	0.06	0.07	19.00	67.20	11.9	5.30	0.2 L	2.40	0.525
88 02 24	0.14	0.07	29.00	96.00	1.5	1.43	1.7	4.00	1.600

STATION WQ0986, SOURCE - SHOAL LAKE
SAMPLING LOCATION - SITE 4 LATITUDE 50:24 LONGITUDE 100:37

DATE	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	SULPHATE MG(SO4)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
87 03 17	0.010 L	0.0450	43.00	365.0	---	---	2.50
87 05 06	0.010 L	0.0950	28.00	230.0	3.0	0.95	0.80
87 05 18	0.010	0.1000	28.00	242.0	6.3	1.00	1.30
87 05 26	0.010 L	0.0850	27.50	242.0	5.0	1.30	3.40
87 06 03	0.010 L	0.0900	28.00	240.0	5.0	1.20	0.40
87 06 11	0.010	0.1050	28.00	240.0	9.5	1.00	2.90
87 06 19	0.010	0.5500	28.00	248.0	15.0	0.40	1.30
87 06 23	0.010	0.1500	30.00	252.0	11.5	1.00	0.00
87 07 01	0.010 L	0.2500	30.00	255.0	45.0	0.50	0.90
87 07 09	0.010 L	0.1350	18.00	250.0	16.0	0.75	2.90
87 07 15	0.010	0.1350	33.00	258.0	8.0	0.75	3.80
87 07 22	0.010 L	0.1400	28.00	248.0	10.0	0.90	0.40
87 07 29	0.010 L	0.1000	33.00	255.0	5.5	0.75	1.70
87 08 05	0.010 L	0.0950	30.00	250.0	11.5	1.00	0.40
87 08 12	0.010	0.1600	28.00	250.0	22.5	0.75	3.40
87 08 19	0.010 L	0.1400	30.00	255.0	15.5	0.50	3.40
87 08 25	0.010 L	0.1350	33.00	265.0	11.0	0.50	3.40
87 09 02	0.010 L	0.1400	30.00	260.0	18.0	0.50	2.50
87 09 08	0.010 L	0.1500	33.00	262.0	9.5	0.40	1.70
87 09 13	0.010 L	0.1350	30.00	248.0	13.5	0.50	1.20
87 09 29	0.010	0.1350	30.00	265.0	---	0.50	1.60
87 11 05	0.020	0.0950	30.00	275.0	---	1.05	3.30
88 02 24	0.280	0.0650	48.00	380.0	---	---	0.80

STATION MR0987, SOURCE - SHOAL LAKE
SAMPLING LOCATION - SITE 5 LATITUDE 50:24 LONGITUDE 100:37

DATE	COND US/CM	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L
87 03 17	1240.0	7.80	252.	307.	0.0	0.0	48.90	71.30	416.0
87 05 06	856.0	8.65	176.	195.	9.6	0.0	39.40	55.90	326.0
87 05 18	862.0	8.65	184.	210.	7.2	0.0	43.40	55.60	338.0
87 05 26	864.0	8.80	186.	198.	14.4	0.0	40.80	49.50	304.0
87 06 03	874.0	8.40	190.	227.	2.4	0.0	42.80	51.60	319.0
87 06 11	874.0	8.55	190.	222.	4.8	0.0	46.20	54.90	342.0
87 06 19	883.0	8.65	190.	222.	4.8	0.0	45.70	53.70	335.0
87 06 23	878.0	8.75	192.	210.	12.0	0.0	46.80	54.60	342.0
87 07 01	868.0	8.90	192.	195.	19.2	0.0	45.90	53.80	335.0
87 07 09	881.0	9.00	194.	193.	21.6	0.0	46.10	55.80	345.0
87 07 15	910.0	8.85	194.	203.	16.8	0.0	45.20	56.50	346.0
87 07 23	900.0	9.00	190.	188.	21.6	0.0	41.90	52.70	322.0
87 07 29	841.0	9.30	168.	142.	31.2	0.0	36.10	56.40	322.0
87 08 05	882.0	8.90	174.	178.	16.8	0.0	38.70	55.50	325.0
87 08 12	850.0	9.00	178.	163.	26.4	0.0	37.80	55.20	322.0
87 08 19	884.0	9.15	182.	168.	26.4	0.0	37.30	54.20	316.0
87 08 25	871.0	9.25	178.	149.	33.6	0.0	37.80	53.20	314.0
87 09 02	860.0	9.10	178.	163.	26.4	0.0	37.10	57.10	327.0
87 09 08	869.0	9.15	178.	163.	26.4	0.0	39.30	56.70	332.0
87 09 13	874.0	9.10	176.	171.	21.6	0.0	39.10	57.90	337.0
87 09 29	894.0	8.95	180.	176.	21.6	0.0	37.90	58.90	337.0
87 11 05	879.0	8.00	182.	222.	0.0	0.0	43.70	56.60	342.0
88 02 24	1300.0	7.70	266.	325.	0.0	0.0	58.10	80.00	475.0

STATION WQ0987, SOURCE - SHOAL LAKE
SAMPLING LOCATION - SITE 5 LATITUDE 50:24 LONGITUDE 100:37

DATE	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L
87 03 17	0.09	0.02	26.00	92.80	0.1 L	0.46	8.3	3.50	0.840
87 05 06	0.06	0.02	18.50	67.70	11.6	2.40	6.4	1.75	---
87 05 18	0.07	0.02	18.50	62.50	8.5	3.40	4.0	1.85	---
87 05 26	2.08	0.04	19.00	56.80	11.2	3.80	1.8	2.15	0.020 L
87 06 03	0.08	0.06	18.50	57.90	8.0	5.30	1.1	2.10	0.130
87 06 11	0.10	0.08	19.50	63.10	7.9	2.40	1.0	2.30	0.230
87 06 19	0.08	0.07	19.00	62.70	7.5	4.30	1.4	3.05	0.032
87 06 23	0.11	0.07	16.50	62.10	8.9	5.50	1.8	2.10	0.050
87 07 01	0.13	0.05	18.50	64.80	8.4	3.90	2.6	2.20	0.003
87 07 09	0.12	0.04	20.50	66.60	8.9	2.60	0.9	2.15	0.050
87 07 15	0.14	0.03	19.50	66.30	9.3	3.70	0.7	2.55	0.040
87 07 23	0.13	0.04	20.00	62.60	9.1	4.00	0.3	2.45	0.072
87 07 29	0.07	0.05	18.00	64.70	15.6	9.90	0.2	2.10	0.008
87 08 05	0.12	0.04	20.00	67.00	6.4	2.00	1.4	3.05	0.006
87 08 12	0.12	0.03	20.50	66.10	8.9	5.10	1.6	2.55	0.005
87 08 19	0.14	0.04	19.50	64.90	9.4	8.20	1.3	2.95	0.005
87 08 25	0.11	0.06	19.50	63.70	12.1	6.80	1.0	2.90	0.007
87 09 02	0.16	0.04	22.00	68.30	8.7	8.40	0.9	2.70	0.006
87 09 08	0.18	0.05	21.00	70.20	10.3	11.00	0.4	2.80	0.004
87 09 13	0.19	0.04	22.00	71.60	9.5	7.40	0.3	2.95	0.005
87 09 29	0.08	0.05	21.00	70.70	8.6	8.30	0.2 L	2.90	0.100
87 11 05	0.06	0.10	19.00	68.40	12.0	5.30	0.2 L	3.35	0.505
88 02 24	0.12	0.06	28.50	95.90	1.0	0.96	1.5	3.90	1.600

STATION WQ0987, SOURCE - SHOAL LAKE
SAMPLING LOCATION - SITE 5 LATITUDE 50:24 LONGITUDE 100:37

DATE	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	SULPHATE MG(SO4)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
87 03 17	0.010 L	0.0450	43.00	375.0	---	---	3.50
87 05 06	0.020	0.0950	28.00	230.0	3.0	1.10	0.00
87 05 18	0.010 L	0.1000	28.00	245.0	5.0	1.10	0.90
87 05 26	0.010 L	0.0950	27.50	242.0	6.5	1.40	1.30
87 06 03	0.010	0.1050	28.00	238.0	2.0	1.30	2.10
87 06 11	0.010	0.1150	28.00	242.0	---	1.00	3.80
87 06 19	0.010 L	0.2500	28.00	250.0	22.0	0.40	0.40
87 06 23	0.010 L	0.1850	28.00	255.0	13.0	0.75	2.50
87 07 01	0.010 L	0.2950	30.00	253.0	39.0	0.40	1.70
87 07 09	0.010 L	0.1350	18.00	245.0	13.0	0.75	1.70
87 07 15	0.010 L	0.1400	30.00	255.0	16.5	0.50	0.80
87 07 23	0.010	0.1450	30.00	248.0	9.5	0.90	3.40
87 07 29	0.010 L	0.1000	33.00	260.0	9.5	1.00	1.20
87 08 05	0.010 L	0.1250	30.00	250.0	16.5	0.90	3.40
87 08 12	0.020	0.1450	28.00	248.0	26.0	0.75	3.00
87 08 19	0.010 L	0.1650	30.00	258.0	22.0	0.50	3.80
87 08 25	0.010 L	0.1550	33.00	265.0	13.5	0.50	1.70
87 09 02	0.010 L	0.1400	30.00	258.0	15.5	0.75	3.00
87 09 08	0.010 L	0.1450	33.00	262.0	9.5	0.40	1.70
87 09 13	0.010 L	0.1400	33.00	255.0	10.0	0.50	3.40
87 09 29	0.090	0.1300	30.00	270.0	---	0.50	2.50
87 11 05	0.030	0.0800	33.00	270.0	---	1.10	1.70
88 02 24	0.050	0.0550	45.00	370.0	---	---	2.20

STATION WQ0988, SOURCE - SHOAL LAKE
SAMPLING LOCATION - SITE 6 LATITUDE 50:23 LONGITUDE 100:37

DATE	COND US/CM	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L
87 03 17	1250.0	7.75	256.	312.	0.0	0.0	48.30	71.02	415.0
87 05 06	856.0	8.65	176.	195.	9.6	0.0	38.80	55.60	326.0
87 05 18	855.0	8.60	184.	215.	4.8	0.0	41.90	52.50	321.0
87 05 26	864.0	8.70	188.	210.	0.0	0.0	40.80	49.30	304.0
87 06 03	874.0	8.30	188.	229.	0.0	0.0	41.60	50.70	313.0
87 06 11	895.0	8.55	192.	225.	4.8	0.0	46.00	54.80	340.0
87 06 19	890.0	8.55	192.	224.	4.8	0.0	45.70	53.60	335.0
87 06 23	876.0	8.70	190.	203.	14.4	0.0	47.30	55.40	346.0
87 07 01	894.0	8.90	196.	200.	19.2	0.0	45.00	53.90	335.0
87 07 09	881.0	8.85	194.	198.	19.2	0.0	45.80	55.00	340.0
87 07 15	889.0	8.85	194.	203.	16.8	0.0	45.50	57.10	350.0
87 07 22	892.0	8.95	196.	200.	19.2	0.0	42.00	52.30	320.0
87 07 29	841.0	9.30	162.	120.	38.4	0.0	34.20	55.60	314.0
87 08 05	882.0	8.90	176.	176.	19.2	0.0	39.40	56.50	331.0
87 08 12	843.0	9.00	178.	173.	21.6	0.0	37.80	55.20	322.0
87 08 19	883.0	9.15	178.	163.	26.4	0.0	37.60	54.20	317.0
87 08 25	854.0	9.20	180.	151.	33.6	0.0	36.20	55.50	319.0
87 09 02	855.0	9.10	174.	154.	28.8	0.0	36.20	56.60	324.0
87 09 08	866.0	9.15	178.	168.	24.0	0.0	39.30	56.70	332.0
87 09 13	874.0	9.15	176.	156.	28.8	0.0	38.50	57.90	335.0
87 09 29	892.0	9.00	178.	178.	19.2	0.0	38.30	59.10	339.0
87 11 05	878.0	7.80	182.	222.	0.0	0.0	42.80	54.90	333.0
88 02 24	1296.0	7.65	264.	322.	0.0	0.0	58.70	80.50	478.0

STATION WQ0988, SOURCE - SHOAL LAKE
SAMPLING LOCATION - SITE 6 LATITUDE 50:23 LONGITUDE 100:37

DATE	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L
87 03 17	0.09	0.05	26.50	91.00	0.1 L	0.74	8.5	3.40	0.920
87 05 06	0.06	0.02	18.50	67.40	11.5	3.30	6.2	2.05	---
87 05 18	0.07	0.04	18.50	63.50	8.6	3.00	4.0	1.95	---
87 05 26	0.08	0.03	19.00	56.20	10.2	4.90	1.2	2.10	0.020
87 06 03	0.08	0.06	18.50	57.30	8.3	5.10	0.6	2.20	0.120
87 06 11	0.12	0.06	19.50	63.00	7.5	3.50	1.0	2.25	0.280
87 06 19	0.09	0.07	19.00	62.50	8.8	5.30	1.2	2.65	0.020
87 06 23	0.10	0.06	17.00	62.90	9.3	5.20	1.6	2.00	0.019
87 07 01	0.09	0.04	20.00	64.40	8.3	4.70	2.2	2.15	0.012
87 07 09	0.12	0.04	20.50	66.00	5.3	3.00	1.5	2.35	0.175
87 07 15	0.21	0.11	19.50	66.50	9.3	3.80	0.6	2.70	0.030
87 07 22	0.13	0.05	20.50	61.00	8.8	3.30	0.4	2.55	0.115
87 07 29	0.09	0.03	18.00	64.60	15.9	13.00	0.2	2.10	0.010
87 08 05	0.13	0.03	20.00	68.60	6.7	2.10	1.4	2.50	0.026
87 08 12	0.12	0.03	20.50	66.00	8.7	4.60	1.6	2.80	0.005
87 08 19	0.16	0.04	19.50	64.70	10.0	10.00	1.4	3.15	0.005
87 08 25	0.02 L	0.02 L	20.00	67.30	11.5	9.20	0.9	2.70	0.005
87 09 02	0.17	0.04	21.50	68.30	9.5	3.90	0.9	2.80	0.010
87 09 08	0.18	0.04	21.50	70.00	9.5	8.40	0.4	2.70	0.004
87 09 13	0.17	0.04	20.00	71.60	10.3	8.10	0.3	2.95	0.004
87 09 29	0.08	0.05	21.00	70.50	8.5	8.00	0.4	2.85	0.365
87 11 05	0.06	0.07	19.00	66.00	11.8	3.10	0.3	3.75	0.520
88 02 24	0.13	0.06	28.50	96.20	0.6	0.88	1.7	3.90	1.700

STATION WQ0988, SOURCE - SHOAL LAKE
SAMPLING LOCATION - SITE 6 LATITUDE 50:23 LONGITUDE 100:37

DATE	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	SULPHATE MG(SO4)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
87 03 17	0.010 L	0.0550	43.00	375.0	---	---	1.70
87 05 06	0.010 L	0.0950	28.00	230.0	3.5	1.00	2.00
87 05 18	0.010 L	0.0900	25.00	245.0	4.0	1.00	0.00
87 05 26	0.010 L	0.0900	27.50	242.0	6.0	1.20	3.70
87 06 03	0.010	0.0800	28.00	242.0	3.0	1.20	2.50
87 06 11	0.010	0.1050	28.00	245.0	7.0	3.30	1.00
87 06 19	0.010 L	0.1600	28.00	250.0	27.0	0.60	0.80
87 06 23	0.010 L	0.1550	28.00	255.0	11.5	0.75	3.30
87 07 01	0.010 L	0.1550	30.00	243.0	15.0	0.90	2.90
87 07 09	0.010	0.1250	18.00	250.0	26.5	1.00	0.80
87 07 15	0.010 L	0.2050	30.00	253.0	19.5	0.50	3.30
87 07 22	0.020	0.1450	30.00	248.0	8.5	0.75	3.30
87 07 29	0.010 L	0.1200	33.00	262.0	12.0	0.75	1.20
87 08 05	0.010	0.1250	30.00	255.0	13.5	0.75	2.10
87 08 12	0.010 L	0.1650	28.00	250.0	31.5	0.50	0.80
87 08 19	0.010 L	0.1950	30.00	252.0	21.5	0.50	2.00
87 08 25	0.010 L	0.1450	33.00	265.0	10.5	0.50	0.40
87 09 02	0.010 L	0.1300	33.00	262.0	13.0	0.75	2.50
87 09 08	0.010 L	0.1500	33.00	262.0	7.5	0.40	0.00
87 09 13	0.010 L	0.1200	30.00	260.0	9.0	0.50	1.20
87 09 29	0.030	0.1100	30.00	265.0	---	0.50	0.40
87 11 05	0.020	0.1050	33.00	275.0	---	0.90	2.10
88 02 24	0.220	0.0600	45.00	370.0	---	---	2.80

STATION MQ0989, SOURCE - SHOAL LAKE
SAMPLING LOCATION - OUTLET LATITUDE 50:23 LONGITUDE 100:37

DATE	COND US/CM	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L
87 04 04	989.0	7.30	328.	400.	0.0	0.0	56.20	59.20	384.0
87 04 12	809.0	7.55	162.	198.	0.0	0.0	40.00	51.60	312.0
87 04 26	846.0	7.95	172.	210.	0.0	0.0	39.10	52.40	314.0
87 05 06	856.0	8.65	176.	200.	7.2	0.0	40.30	53.00	319.0
87 05 18	855.0	8.65	182.	207.	7.2	0.0	41.00	51.90	316.0
87 05 26	864.0	8.75	186.	198.	14.4	0.0	40.80	49.80	304.0
87 06 03	874.0	7.95	192.	234.	0.0	0.0	42.00	51.20	316.0
87 06 11	874.0	8.45	190.	227.	2.4	0.0	45.90	55.00	341.0
87 06 19	883.0	8.65	192.	220.	7.2	0.0	45.20	53.30	332.0
87 06 23	894.0	8.95	190.	203.	14.4	0.0	47.60	55.10	346.0
87 07 01	885.0	8.85	196.	200.	19.2	0.0	44.70	52.90	329.0
87 07 09	908.0	8.65	196.	220.	9.6	0.0	45.90	55.50	343.0
87 07 15	901.0	8.75	192.	205.	14.4	0.0	46.00	57.00	350.0
87 07 22	903.0	8.90	192.	195.	19.2	0.0	42.40	53.00	324.0
87 07 29	911.0	6.55	210.	256.	0.0	0.0	41.30	57.70	341.0
87 08 05	894.0	8.40	178.	212.	2.4	0.0	39.74	56.00	330.0
87 08 12	859.0	8.90	178.	188.	14.4	0.0	38.30	55.20	323.0
87 08 19	881.0	9.20	180.	161.	28.8	0.0	38.80	53.70	318.0
87 08 25	857.0	9.15	180.	161.	28.8	0.0	39.10	57.20	333.0
87 09 02	868.0	9.00	176.	161.	26.4	0.0	36.90	56.70	325.0
87 09 08	866.0	9.20	176.	151.	31.2	0.0	39.10	56.30	330.0
87 09 13	874.0	9.15	176.	166.	24.0	0.0	38.20	57.60	333.0
87 09 29	900.0	8.45	184.	215.	4.8	0.0	38.60	59.40	341.0
87 11 05	886.0	7.85	182.	222.	0.0	0.0	42.20	54.80	332.0
88 02 24	2070.0	7.00	1120.	1370.	0.0	0.0	147.00	121.00	866.0

STATION MQ0989, SOURCE - SHOAL LAKE
SAMPLING LOCATION - OUTLET LATITUDE 50:23 LONGITUDE 100:37

DATE	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L
87 04 04	1.52	0.66	24.50	51.20	---	7.20	22.2	2.35	---
87 04 12	0.16	0.15	17.50	60.50	---	3.70	7.2	2.20	---
87 04 26	0.09	0.06	17.50	61.70	---	1.50	7.8	2.30	---
87 05 06	0.06	0.03	18.50	64.30	11.6	2.50	6.1	1.80	---
87 05 18	0.06	0.03	18.50	61.00	9.5	2.80	4.0	2.10	---
87 05 26	0.06	0.05	19.00	56.30	12.1	3.70	0.8	1.95	0.020 L
87 06 03	0.11	0.09	19.00	58.10	5.2	5.30	1.2	2.20	0.195
87 06 11	0.12	0.06	19.50	63.00	7.6	3.40	0.8	2.40	0.230
87 06 19	0.11	0.08	19.00	62.20	9.3	3.80	1.2	2.65	0.011
87 06 23	0.10	0.09	18.50	62.50	10.1	11.00	1.8	2.15	0.013
87 07 01	0.11	0.06	19.00	63.40	7.7	4.70	2.6	2.30	0.040
87 07 09	0.16	0.05	20.50	65.50	3.9	4.10	1.6	2.35	0.230
87 07 15	0.16	0.05	21.00	66.20	9.3	9.30	0.4	2.75	0.090
87 07 22	0.15	0.06	20.50	62.10	8.8	6.50	0.2	2.80	0.062
87 07 29	0.22	0.15	21.00	66.20	6.5	---	0.2	5.40	0.015
87 08 05	0.15	0.06	20.00	67.80	4.4	417.00	1.3	4.05	0.330
87 08 12	0.13	0.04	21.00	65.80	8.2	8.20	1.6	3.00	0.007
87 08 19	0.27	0.05	20.00	64.40	11.3	9.70	1.5	3.75	0.005
87 08 25	0.12	0.04	20.00	69.30	11.5	3.00	1.0	3.50	0.006
87 09 02	0.28	0.05	22.00	68.40	8.0	6.00	0.9	2.90	0.008
87 09 08	0.18	0.04	20.50	69.60	10.6	5.00	0.4	3.10	0.004
87 09 13	0.18	0.04	21.50	70.90	10.5	5.40	0.4	2.80	0.003
87 09 29	0.08	0.05	21.00	71.40	5.0	2.80	0.3	2.80	0.365
87 11 05	0.05	0.08	19.00	65.40	12.2	2.90	0.2 L	3.25	0.505
88 02 24	1.69	1.25	20.50	119.00	0.0	53.00	50.0	12.00	7.120

STATION WQ0989, SOURCE - SHOAL LAKE
SAMPLING LOCATION - OUTLET LATITUDE 50:23 LONGITUDE 100:37

DATE	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	SULPHATE MG(SO4)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
87 04 04	0.020	0.6000	35.00	163.0	---	---	0.20
87 04 12	0.220	0.2100	30.00	223.0	---	---	0.20
87 04 26	0.030	0.1000	28.00	230.0	---	---	0.20
87 05 06	0.010 L	0.0950	28.00	235.0	2.5	0.60 G	0.30
87 05 18	0.010 L	0.0900	28.00	240.0	5.0	0.60 G	0.30
87 05 26	0.010 L	0.0800	27.50	242.0	6.0	0.60 G	0.30
87 06 03	0.020	0.0950	28.00	235.0	5.5	0.90 G	0.50
87 06 11	0.010	0.0850	28.00	245.0	7.5	0.40 G	0.20
87 06 19	0.010 L	0.1250	28.00	252.0	15.5	0.60 G	0.30
87 06 23	0.010 L	0.1350	28.00	250.0	18.5	0.60 G	0.30
87 07 01	0.010 L	0.1400	30.00	248.0	21.5	0.60 G	0.30
87 07 09	0.010 L	0.1350	18.00	250.0	10.0	0.60 G	0.30
87 07 15	0.010 L	0.1700	30.00	255.0	11.0	0.60 G	0.30
87 07 22	0.010 L	0.1950	30.00	248.0	19.0	0.60 G	0.30
87 07 29	0.010 L	0.4700	33.00	262.0	2090.0	0.50 G	0.25
87 08 05	0.010 L	0.1900	30.00	250.0	17.5	0.50 G	0.25
87 08 12	0.010 L	0.1850	28.00	250.0	28.5	0.50 G	0.25
87 08 19	0.010 L	0.2850	30.00	255.0	38.0	0.50 G	0.25
87 08 25	0.010 L	0.2350	33.00	265.0	11.0	0.50 G	0.25
87 09 02	0.010 L	0.1550	30.00	258.0	15.5	0.50 G	0.25
87 09 08	0.010 L	0.1500	30.00	265.0	11.0	0.50 G	0.25
87 09 13	0.010 L	0.1150	30.00	260.0	9.5	0.50 G	0.25
87 09 29	0.040	0.1150	30.00	250.0	---	---	0.10
87 11 05	0.030	0.0850	33.00	272.0	---	0.40 G	0.20
88 02 24	0.010 L	2.1000	55.00	84.0	---	---	0.05

Appendix II: TOWN OF SHOAL LAKE SEWAGE LAGOON EFFLUENT NUTRIENT DATA

Date	Time	Total Kjeldhal Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	$NO_3^-NO_2$ Nitrogen (mg/L)	Total Phosphorus (mg/L)
May 12, 1987	11:00	8.75	4.50	1.55	4.50
May 13, 1987	11:00	9.00	4.50	1.50	4.55
May 13, 1987	17:00	14.5	9.25	0.47	4.40
May 14, 1987	10:00	16.5	13.5	0.13	4.20
May 14, 1987	17:00	18.0	13.8	0.14	4.20
May 15, 1987	11:00	15.5	12.8	0.11	4.00
May 15, 1987	17:00	15.5	13.2	0.11	3.95
May 18, 1987	17:00	8.75	4.40	1.50	4.50
May 19, 1987	10:30	9.50	7.00	0.09	2.75
May 20, 1987	8:30	9.75	6.75	0.10	2.70

Appendix III: CALCULATION OF PHOSPHORUS EXCRETION BY A COW

The following statistics pertain to a 450 Kg (1000 lb) beef cow which may be either pregnant or lactating. Values were provided by Dr. Ray Engels, Professor, Animal Science, University of Manitoba and by Ms. Karen Dupchak, Assistant Provincial Animial Nutritionist, Agricultural Development and Marketing.

Forage consumption:	10.9 - 11.4 Kg (dry weight) per day
Forage phosphorus content:	0.1 - 0.35% (dry weight)
Phosphorus conversion rate:	55% (i.e. 45% escapement)

Mean annual phosphorus escapement = mean forage consumption x mean forage phosphorus content x phosphorus conversion rate x 365 days;

= 11.15 Kg x 0.225% x 55% x 365 days

= 5.036 Kg phosphorus per year.